LEARNING STRATEGY PREFERENCES, VERBAL-VISUAL COGNITIVE STYLES, AND MULTIMEDIA PREFERENCES FOR CONTINUING ENGINEERING EDUCATION INSTRUCTIONAL DESIGN

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Abstract:

A literature search revealed very little information on how to teach working engineers, which became the motivation for this research. Effective training is important for a wide range of reasons such as preventing accidents, maximizing fuel efficiency, minimizing pollution emissions, and reducing equipment downtime. The conceptual framework for this study included the development of a new instructional design framework called the Multimedia Cone of Abstraction (MCoA). This was developed by combining Dale's Cone of Experience and Mayer's Cognitive Theory of Multimedia Learning. An anonymous survey of 118 engineers from a single Midwestern manufacturer was conducted to determine their demographics, learning strategy preferences, verbal-visual cognitive styles, and multimedia preferences.

The learning strategy preference profile and verbal-visual cognitive styles of the sample were statistically significantly different than the general population. The working engineers included more Problem Solvers and were much more visually-oriented than the general population. To study multimedia preferences, five of the seven levels in the MCoA were used. Eight types of multimedia were compared in four categories (types in parantheses): text (text and narration), static graphics (drawing and photograph), non-interactive dynamic graphics (animation and video), and interactive dynamic graphics (simulated virtual reality and real virtual reality).

The first phase of the study examined multimedia preferences within a category. Participants compared multimedia types in pairs on dual screens using relative preference, rating, and ranking. Surprisingly, the more abstract multimedia (text, drawing, animation, and simulated virtual reality) were preferred in every category to the more concrete multimedia (narration, photograph, video, and real virtual reality), despite the fact that most participants had relatively little prior subject knowledge. However, the more abstract graphics were only slightly preferred to the more concrete graphics.

In the second phase, the more preferred multimedia types in each category from the first phase were compared against each other using relative preference, rating, and ranking and overall rating and ranking. Drawing was the most preferred multimedia type overall, although only slightly more than animation and simulated virtual reality. Text was a distant fourth. These results suggest that instructional content for continuing engineering education should include problem solving and should be highly visual.

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CHAPTER I

INTRODUCTION

Background

Continuing Education for Working Engineers

Continuing education is critical for working engineers because of the breadth of processes and equipment they design and use and because of rapid changes in technology. For example, plant engineers take courses to learn how to operate different types of equipment specific to their operations (Baukal & Crawford-Fanning, 2013; Valencia, Link, Baukal, & McGuire, 2008). This training takes a variety of forms including traditional classroom, on-the-job, and computer-based training (CBT). Classroom training is led by an instructor or facilitator. In on-the-job training, a more-experienced employee trains a less-experienced colleague on specific procedures and operations. This is usually less structured but more personalized than classroom training. CBT involves course materials delivered by computer, often over the Internet (Baukal, 2010). CBT instruction is increasingly important in delivering continuing training for working engineers and is the subject of the present study, although the results are relevant for any type of training for working engineers.

There are two general types of online training: synchronous and asynchronous (Moore & Kearsley, 2005). In *synchronous* training, an instructor and one or more students are online at the same time, interacting with each other in real time. In *asynchronous* training, the participants are not usually online at the same time and the courses may or may not be instructor-led. Online courses without an instructor are generally referred to as *standalone* or *self-directed* (Horton & Horton, 2003) and are typically used to provide learners with information but not usually to teach new skills (Colbrunn & Van Tiem, 2002). Many companies use asynchronous self-directed courses to provide their employees with periodic legal, safety, and environmental training. These courses are generally short in length and can be completed at the convenience of the participants.

As an experienced professional in in-service engineering training, this researcher has observed that instructional and graphic design are major challenges for self-directed courses, which are often poorly designed with too much text, not enough graphics, and very little interaction between learners and course materials or each other. These courses are frequently developed by subject matter experts who know the content, but not instructional design principles. Poor design and weak learner appeal are problematic because employees have no option to avoid or opt out. They must take these mandatory courses, frequently with the attitude of completing them as quickly as possible. This situation and its detrimental effect on employee learning as an important aspect of a company's human capital provided the impetus for this study. The particular focus in the present study is how to properly design online continuing education courses for engineers.

Context and Setting for This Study

The John Zink Company (JZC), headquartered in Tulsa, Oklahoma, manufactures combustion equipment which is used in refineries and chemical plants worldwide (Baukal, 2001). The participants in the research were engineers working at JZC who develop, sell, design, manufacture, test, and service that equipment. The John Zink Institute (JZI) is an organization within JZC that offers technical training to customers and employees on JZC's equipment. JZI represents the training model popularized late in the 20th century under the general name of the *corporate university*. Meister (1998, p. 38) defined a corporate university as a ". . . centralized strategic umbrella for the education and development of employees . . . [which] is the chief vehicle for disseminating an organization's culture and fostering . . . job skills, but also . . . core workplace skills. . . ."

Shorter versions of the JZI courses are given at clients' locations (Baukal & Crawford-Fanning, 2013; Gilder, Campbell, Robertson, & Baukal, 2010; Valencia, Link, Baukal, & McGuire, 2008), while the more comprehensive versions are offered at JZI's training facility in Tulsa, Oklahoma. A popular two-day face-to-face class called Process Burner Fundamentals has an online course prerequisite that must be completed before students come to Tulsa for the face-to-face course (Baukal, 2008). This short online course, referred to as Process Burner Theory, was designed by this researcher and consists of 16 modules that take approximately 15-20 minutes each to complete as recommended for asynchronous online content (Carliner, 2002). The primary students taking these classes are adult engineers working in refineries and chemical plants who need this knowledge to safely and efficiently operate process burners while minimizing pollution and downtime.

Self-directed asynchronous online courses can be used for several specific purposes. Two common functions are (1) to teach fundamental principles, and (2) to supplement classroom training (Baukal, 2008). These functions help ensure all students have at least a minimum knowledge level before taking a course. In Process Burner Fundamentals, students need to have some basic entering knowledge of combustion, heat transfer, and fluid flow. In the original version of the classroom course, some students felt too much time was spent on those basics while others felt not enough time was spent. This was one reason for developing the online theory course so students could go as slow or as fast as they wanted to learn the prerequisite fundamentals, as long as all modules were completed prior to attending the face-to-face Process Burner Fundamentals course.

The modules in the online fundamentals course were originally taught as part of the face-to-face course. The instructors struggled to cover the course materials in the allotted two days. Another reason for developing the online course was to move approximately three hours of content out of the face-to-face course to give instructors more time to cover other content. However, in moving the instructional content from its original classroom context, little effort was made to adapt the materials specifically for online instruction. This may have created weak instructional designs for the online modules.

Online courses need to be well designed. Many are mandatory for company employees and must be taken repeatedly, so it is particularly important that they are well designed because the content is important enough that it must be refreshed on a regular basis. Self-directed asynchronous online courses must be well designed so students can easily complete the materials and master the content on their own. Because of their increasing usage, it is important that online courses are designed based on research principles (Clark, 2005), both to increase student learning and to motivate students to take them (Martens, Bastiaens, & Kirschner, 2007). Learning can be inhibited if learners are not motivated, and "some media may be perceived as more interesting than others, therefore producing positive learning effects by influencing students to spend more effort on the task" (Moreno, 2005, p. 4).

Despite an extensive literature review, the researcher found no recommendations for designing online courses for the continuing education of professional engineers. While much research has been done on educating engineering *university students*, apparently very little has been done on the continuing education of *working* engineers. This is not surprising as engineering disciplines have received relatively little attention from learning sciences researchers (Johri & Olds, 2011). This suggested to the researcher a need for empirical study in this area.

Multimedia and Learning

Many types of multimedia do not require an instructor for delivery and can be used in a variety of educational settings, including the self-directed online context of interest in this study. Multimedia used in online courses can be as effective as a traditional classroom (Clark, 2005). For example, Buzzell, Chamberlain, and Pintauro (2002) showed that web-based tutorials incorporating multimedia were as effective as traditional classroom lectures for teaching human body composition analysis.

In a learning context, there are often many ways to illustrate subject matter (Schnotz & Bannert, 2003), such as using different types of multimedia. While some studies have shown improvements in learning using multimedia compared to not using multimedia, other studies have shown no significant difference between learning with and without multimedia (e.g., Höffler & Schwartz, 2011).

An important factor in learning with multimedia is determining factors that differentiate learners, which has received relatively limited research (Samaras, Giouvanakis, Bousiou, & Tarabanis, 2006). This is particularly the case for working engineers. Some of those factors are considered next.

Learning Strategy and Style Preferences of Adult Learners

Samaras, Giouvanakis, Bousiou, and Tarabanis (2006, p. 25) wrote, “There is a need for further research to determine a framework for designing effective adaptable multimedia learning environments that will be compatible with particular learning preferences, strengths, weaknesses, and behaviors of students, and will lead to efficient and better learning." Two learning preferences were examined in this study: learning strategy and verbal-visual preferences.

Learning strategy preferences are important characteristics that vary among learners. Conti and Fellenz (1991, p. 1) defined learning strategies as "techniques or skills that an individual elects to use in order to accomplish a learning task." Through a complex and lengthy process, an instrument known as ***A***ssessing ***T***he ***L***earning Strategies of ***A***dult***S*** or ATLAS was developed and validated (Conti, 2009). Three distinct learning strategy groups were identified: Navigators, Problem Solvers, and Engagers. Research has shown that certain learning strategy preferences may be more common depending on the group under consideration (e.g., Ausburn & Brown, 2006; Birzer & Nolan, 2002). Learning strategies as defined and measured by ATLAS represent the *strategic aspect of adult learning preferences*. This variable was included in this study to examine possible relationships between strategic learning choices and media preferences.

A major dimension of cognitive style is the *verbalizer-visualizer dimension* (Riding, 2001). People who are better at processing words are known as verbalizers and those better at processing images are known as visualizers. This is a particularly important dimension in the design of multimedia learning environments (Mayer & Massa, 2003). When given a choice, learners will normally choose the mode of presentation that suits their style (Riding & Sadler-Smith, 1997).

The verbalizer/visualizer preference as measured by a question established by Mayer and Massa (2003) represents the *perceptual*/*cognitive aspect of adult learning styles*. This variable was included in this study to examine possible relationships between perceptual/cognitive learning choices and media preferences. It was also included in the study to compare with verbal/visual media preferences.

Theoretical and Conceptual Framework

Dale's Cone of Experience

Dale's Cone of Experience (CoE), shown in Figure 1, is a visual analogy to illustrate the progression of learning experiences from direct, firsthand participation to purely abstract, symbolic expression (Dale, 1969). This iconic model has been influential in the fields of instructional technology and design since it was introduced by Dale in 1946 (Ely, 1970). It was intended to show the level of abstraction for various types of learning activities to help K-12 teachers design appropriate instructional materials using audiovisuals. Grounded in Piagetian psychology (L. J. Ausburn & Ausburn, 2008), Dale's Cone positions various learning experiences according to their level of abstraction or concreteness. The lowest and least abstract level is "Direct Purposeful Experiences" where students participate directly in an activity and use their senses to help learn. The highest and most abstract level of experience is "Verbal Symbols" where students use written symbols to express a concept. For example, H_2O represents the chemical compound for water which shows that water consists of two hydrogen atoms bonded with one oxygen atom. H_2O is a symbolic representation of water.

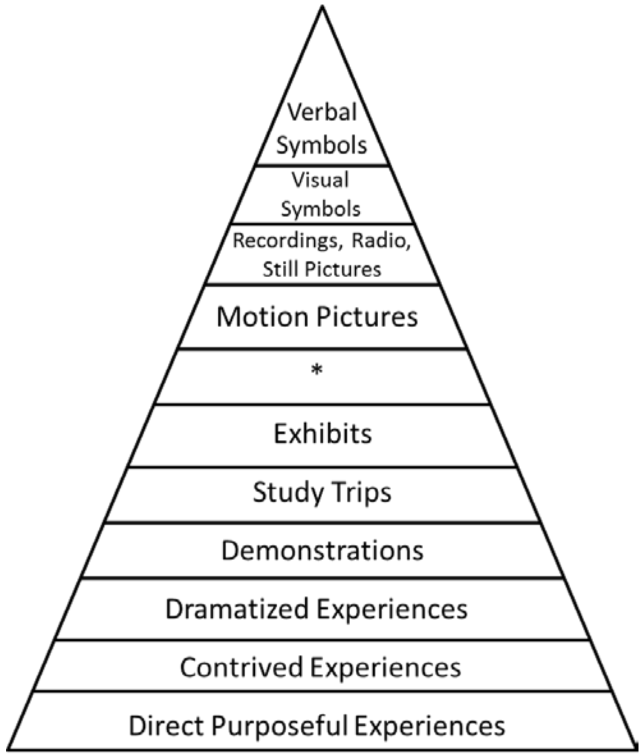


Figure 1. Dale's Cone of Experience.
* Not in 1946 version, "Television" in 1954 version, "Educational TV" in 1969 version.
Source: Dale (1946, 1954, 1969).

Dale (1969) emphasized the CoE was not designed to attribute worth to a particular level, such as the top being better than the bottom or vice versa. Rather, he proposed that in some learning contexts, more direct interaction may be needed, such as when the learner has no previous experience or foundation with a subject. In other learning contexts, symbolic expression may be preferred, such as when a graduate chemistry student no longer needs direct experience and uses the symbol H_2O instead of the word *water*. At a lower level, very young children can only understand the concept of "water" through experiencing it hands-on, while later they can relate simply to the word "water."

Mayer's Cognitive Theory of Multimedia Learning

Multimedia has become an important element in instructional design. Multimedia can be used to effectively communicate complex concepts. It has become easier to develop and use because of advancements in both hardware and software.

There is growing research showing learning is enhanced by well-designed multimedia presentations compared to text-only (Mayer, 2003). Mayer presented some general recommendations for effective instructional design involving multimedia regardless of whether the delivery method is paper-based or computer-based. For example, Mayer claimed that:

1. Graphics plus text is more effective than text-only (p. 131).
2. Extraneous materials, such as interesting but nonessential facts referred to as *seductive details*, should be excluded as they generally reduce learning (p. 132).
3. Graphics should be placed as close as possible to the text they support (p. 133).
4. Text presented in conversational style is more effective than in formal style (p. 134).

Mayer (2009) proposed 12 research-based principles for designing effective multimedia presentations which are based on his Cognitive Theory of Multimedia Learning. This theory was derived from three other theories: (1) Baddeley's Working Memory Theory (Baddeley, 1986, 2007; Baddeley & Hitch, 1974), (2) Paivio's (1986, 2007) Dual Coding Theory, and (3) Sweller's Cognitive Load Theory (Chandler & Sweller, 1991; Sweller, 2005; Sweller, Ayres, & Kalyuga, 2011).

Multimedia Cone of Abstraction

Multimedia has become an important element in instructional design. Virtual reality (VR) is a relatively new element of multimedia which has the potential to show very realistic simulations that were not readily available for teachers when Dale proposed his CoE. Some of the elements in the original CoE are not as relevant today as they were at the time the CoE was first developed. These include, for example, contrived experiences, study trips, exhibits, and educational television. To accommodate new multimedia technologies and eliminate outdated methods, Dale's CoE needed to be updated for today's learning contexts, including the continuing engineering education context for the present study. This theory update/development became a critical prerequisite for this researcher before the proposed study of multimedia in engineering continuing education could have full theory support. The following discussion presents the new MCoA as conceptualized by this researcher and applied as the theoretical underpinning of this study.

Because of the ubiquity of using computers to display instructional content, it was assumed for the theoretical development component of this study that *multimedia specifically refers to materials that can be displayed on a computer.* This is particularly important because of the growth of distance learning using computers. This assumption necessarily limits the senses that can be used in materials delivered by computer to visual and auditory. This means some of the elements in Dale's CoE are not appropriate in a multimedia environment. For example, a study trip where students physically travel to another location would not be included in an updated CoE for the specific context applied here.

Dale's (1969) focus was on the *experience of the learner*, although he admitted his placement of learning experiences on the CoE hierarchy was based on their level of abstraction. However, the impact of experiences can vary among learners and some experiences may be quite similar, such as study trips and exhibits. Therefore, *level of abstraction* appears to be a more relevant way to classify the modality levels, rather than by experience which can be very subjective. The main differences may lie not in the *nature* of the media components, but rather in their *design*. Also, some of Dale's levels appear to be somewhat overlapping. For example, educational television and motion pictures both consist of moving graphics of real images. While the content may vary between the two, they seem to be different variations within the same media category.

Figure 2 shows the conceptual framework for the new Multimedia Cone of Abstraction (MCoA) proposed by this researcher and recently presented to engineering educators (Baukal, Ausburn, & Ausburn, 2013) to underpin this study. As illustrated in Figure 2, Baddeley's Working Memory Theory, Paivio's Dual Coding Theory, and Sweller's Cognitive Load Theory all contributed to Mayer's Cognitive Theory of Multimedia Learning. Combining Dale's Cone of Experience and Mayer's Cognitive Theory of Multimedia Learning yields the researcher's MCoA which provides guidelines for instructional designers using multimedia technologies, particularly via computer, to enhance learning.

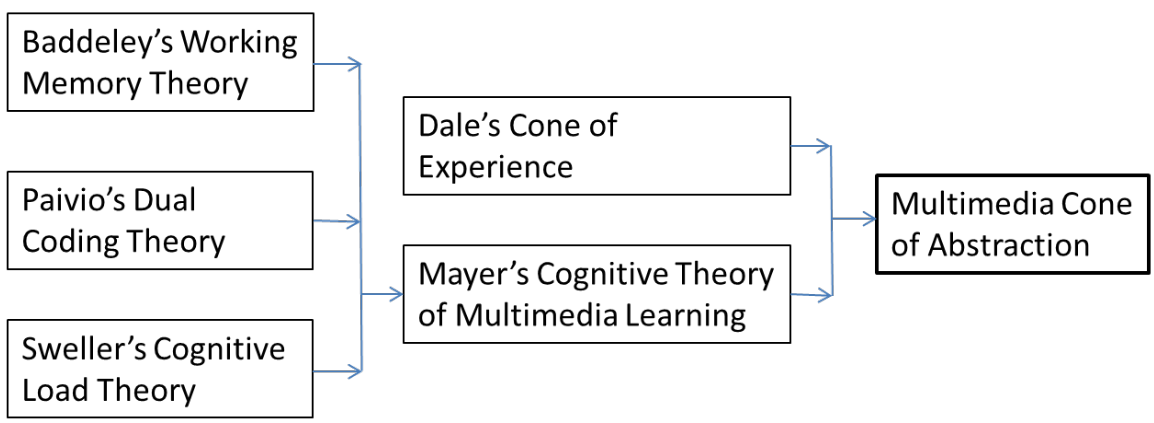


Figure 2. Conceptual framework for the proposed multimedia cone of abstraction.

Figure 3 shows the proposed MCoA designed to update Dale's CoE specifically for the use of multimedia in a learning context. The closer to the bottom of the cone, the more realistic the representation; the closer to the top, the more abstract. The choice of a cone helps symbolize that multimedia towards the bottom is likely to be effective for more learners (novices), compared to the top where fewer learners (experts) possess the knowledge and experience needed to process information in those forms. The levels in the MCoA are consistent with Mayer's Cognitive Theory of Multimedia Learning. There are some relationships among some of the levels which could potentially have been combined, but have been purposely separated. For example, nonverbal audio and narration both involve sound, and symbols are a specific subset of images and text. However, they are distinct forms of multimedia with unique characteristics and therefore have been kept separate here. As will be shown, there are numerous potential combinations of these levels.

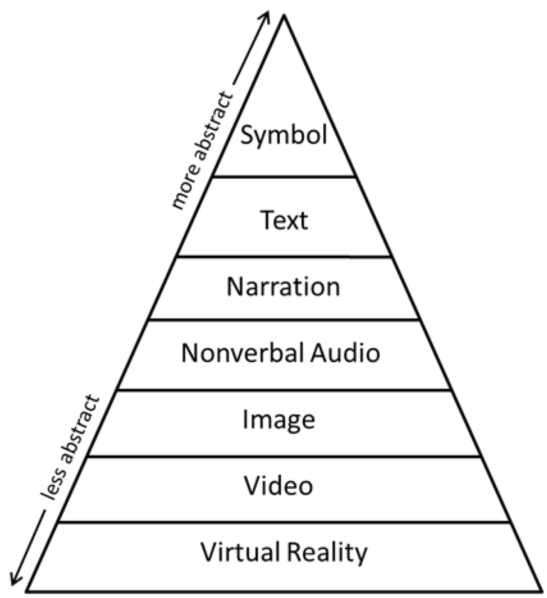


Figure 3. Researcher's proposed Multimedia Cone of Abstraction.

The lowest and least abstract level on the MCoA is *Virtual Reality* (VR). There are two basic types of VR: real and simulated. Real VR is a user-controllable simulation using actual images such as photographs of things like objects or scenes. Today's VR is so realistic that the experience is almost like being there. Simulated VR is also a user-controllable simulation, but using simulated graphics, such as computer-aided drawings, instead of actual photo-real images. While today's drawings can be very realistic, they are not yet as realistic as actual photographs and are therefore more abstract. However, in some learning contexts it may be preferable to use simulated VR because the images could be colored or cut away to highlight specific areas. While actual images can be colored as well, they are then no longer "real" because they have been altered. It may not be as easy to cut away a real image as it is with a simulated image. For example, it would only be possible to “cut away” a mannequin or cadaver if one is interested in looking inside the human body for an anatomy class. It would not be possible to cut away a living creature to look inside for instructional purposes without injuring or killing the specimen. In that case, simulated VR consisting of representational images may be preferred.

It might be argued that the next level, *Video*, should be considered less abstract than VR. However, user-controllability makes VR less abstract than video in a learning environment. With video, the user generally only controls the speed and time sequence of the display (e.g., start, stop, rewind, fast forward), but not the location being viewed (i.e., it has no pan or zoom capability). VR has the added feature that the learner not only controls the speed and time sequence, but also the location being viewed (e.g., zoom in, zoom out, pan left, pan right, pan up, pan down). Further, while learners control the speed and time sequence of a video, in actual practice this capability is rarely used. However, in VR the user *must* control those functions or the image will not move, so learners are forced to control what they are viewing, which typically means they will move at a pace they are most comfortable with and not at the preset pace (e.g., 30 frames per second) of a typical video.

Images are static graphics that may be in multiple formats. Real images are static graphics (e.g., photographs) of an actual object or scene. Simulated images (e.g., drawings) are representations of real images. Images have dimensionality and may be two-dimensional (2D) or three-dimensional (3D). While it might be assumed that more detailed 3D drawings would be superior to less detailed 2D drawings, Butcher (2006) experimentally found that a simplified 2D drawing actually promoted more factual learning than a detailed 3D drawing in the study of the heart and circulatory system. Images may be black-and-white or color. While color is often preferred, in some instances it can be overused where too many colors could overload the learner. Pett and Wilson (1996) found there was no significant improvement in learning with color compared to black and white. While some people are capable of distinguishing 20,000 different colors, using more than 20 to 30 colors may not only have a diminishing returns effect, but may actually have a negative effect on the viewer (Tufte, 1990). Fewer colors or even black-and-white might be better in some learning contexts, to avoid cognitively overloading the learner.

Nonverbal Audio refers to sound other than narration, with narration being considered to be a verbal form at a higher level of abstraction. Nonverbal audio could, for example, be produced during everyday life such as the sounds of traffic in a city. Audio could also be produced by devices designed specifically to make sound, such as musical instruments. Then, there are two types of audio: real and simulated. Real audio is a recording of actual sound, while simulated audio is produced, for example, by a computer which can be used to recreate sounds such as from electronic instruments. Nonverbal audio has the added features of dimensionality where the sound could be mono (1 channel), stereo (2 channels), or surround-sound (multiple channels) and have multiple frequencies (e.g., bass, mid-range, and treble).

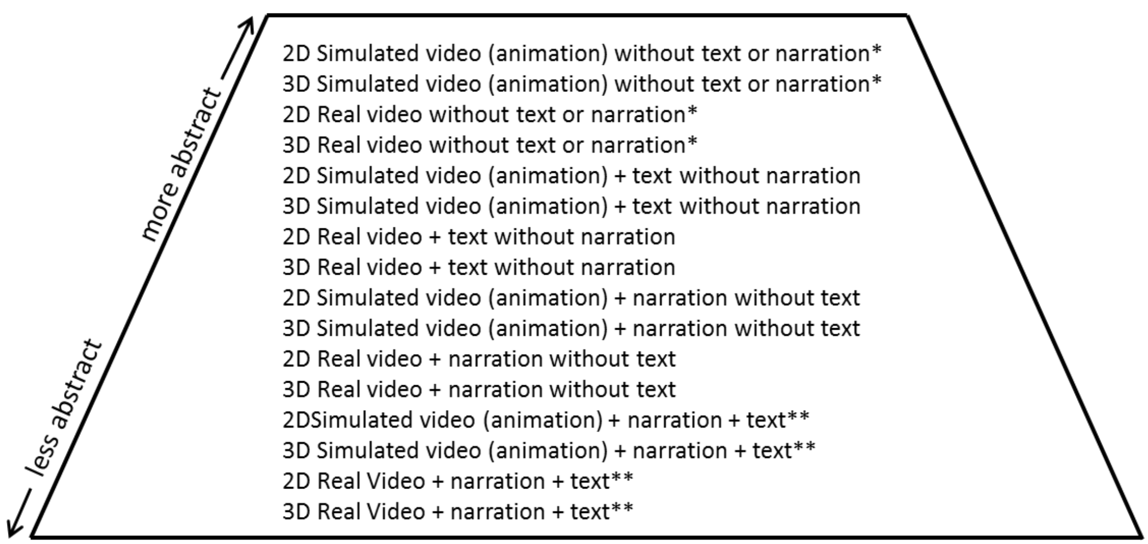
In general, images are considered to be more concrete than nonverbal audio. Consider the adage that “a picture is worth a thousand words” and compare that to a recording of sounds. In most cases, images clearly depict something readily identifiable to the viewer. Pure sound recordings (with no narration) are usually more challenging to identify compared to images and are therefore more abstract. However, there may be circumstances where a sound recording could be more concrete than a particular image. For example a photograph of a car would be less concrete than the recording of a car horn blasting which cannot be discerned in a photo. Then, the levels in Figure 3 are intended to provide the instructional designer with guidelines rather than rigid rules.

Narration is a specific verbal (auditory) form using spoken language with no images or text. Narration is less abstract than the next level – *text* – because the spoken language includes changes in volume and tone that contain additional meaning compared to written words (Mayer, Hegarty, Mayer, & Campbell, 2005). Other aspects of narration include the pace (speed the words are spoken) and the diction (e.g., accent, inflection, intonation, pronunciation) of the narrator.

Text is a verbal form that refers to written words. This may be as simple as a bulleted list or as complicated as a textbook. The assumption is that the language is familiar to the learner, although advanced vocabulary or a language that is not the primary language of the learner can make text even more abstract. The challenge with pure text is that the learner has fewer cues, such as facial expression or voice inflections, to determine the author's meaning. This makes it more abstract than images and narration. There are also many aspects of text that impact learning such as the font type and size, capitalization, paragraph justification, and the use of white space. For example, using an unusual font type, too small a font size, or too little white space can make text difficult to read (Lohr, 2008) and unnecessarily increase the cognitive load on the learner.

Symbol is the most abstract level and requires special prior knowledge by the learner for interpretation. This knowledge may be highly culturally-specific. There are two primary types of symbols: visual and verbal. A visual symbol refers to a graphic that is often short-hand notation for something. For example, a circle with a slash diagonally across it on top of an image is a universal symbol that means not to do whatever is in the image. For example, an image of a cigarette with smoke rising from the lit end that has a circle with a slash on top of it means the area is non-smoking. A purely visual symbol does not have any textual characters and is a more abstract form of a typical image. The learner must be familiar with the symbol for it to be meaningful which is why it is considered more abstract than a non-symbolic image. Visual symbols may be specific to an industry and need to be learned by those working in that industry. For example, an image of a person standing under a shower is the symbol for a safety shower in a chemical plant. Workers need to know what that means in case they ever need to wash off potentially dangerous chemicals. A verbal symbol is usually short-hand notation for something more complex. The example previously given is the verbal symbol for water which is H_2O. This can be further refined to show the state of the water: $H_2O(s)$, $H_2O(l)$, and $H_2O(g)$ refer to water in the solid (ice), liquid, and gaseous (steam) states, respectively.

Within a given level of the MCoA, there may be many sublevels. For example, possible sublevels for the Video level include those shown in Figure 4. The Video sublevels are combinations of video type (simulated or real), dimensionality (2D or 3D), and verbal type (none, text, narration). *Simulated Video* (better known as animation) is where the dynamic representation uses moving simulated graphics such as computer-aided drawings. *Real Video* is a moving (dynamic) representation using actual images, such as those taken with a movie camera. Using today's technology, special glasses are typically required to view 3D videos, whether real or simulated. A verbal component may or may not be present and, if present, it could be in the form of narration, text, or both.



* Less effective because does not take advantages of both memory channels.

** Less effective if text is extensive or duplicates narration because of cognitive overload.

Figure 4. Possible sublevels within the "Video" level of MCoA listed from most abstract (top) to least abstract (bottom).

Not all of the sublevels shown in Figure 4 satisfy Mayer's Cognitive Theory of Multimedia Learning. For example, Baddeley's Working Memory Theory and Paivio's Dual Coding Theory do not recommend using both narration and a substantial amount of text together as they could overload a learner's verbal memory channel. A more effective use of both would be, for example, text labels identifying component parts, with narration that explains each component.

The Video sublevels could be even further expanded if, for example, audio (other than narration) and color (black-and-white, color) were included. The audio would be sounds relevant to the content, but not simply background music as that would violate Mayer's Coherence Principle where extraneous content should be avoided as it distracts the learner. An example of relevant audio might be the sound of a jet engine if the content concerned jet engine maintenance. The volume would likely need to be appropriately reduced as jet engines are very loud. However, because most people are familiar with that sound, it may be preferable to deliberately exclude it as it could be argued it does not add anything substantive to learning and may even reduce learning by distracting the learner.

Prior Knowledge Principle

The researcher's proposed MCoA demonstrates the many levels of abstraction that are available to the instructional designer of educational content. The appropriate amount of abstraction depends on both the subject matter and on the prior knowledge of the learners. For example, students with no prior background in a subject area will likely need less abstract multimedia initially, but will be capable of more abstract multimedia as their knowledge of the subject increases. This is consistent with the Piagetian conceptualization of human development of abstract reasoning competency (Piaget & Inhelder, 1969). Instructional materials need to be tailored to the knowledge level of the learners, which is referred to as the *prior knowledge* *principle* (Kalyuga, 2005; Naryanan & Hegarty, 2002). No single level will be appropriate for all topics. In addition, some levels may not be appropriate for all learners. For example, more visually-oriented learners may prefer virtual reality, while more verbally-oriented learners may prefer narration and text. In a meta-analysis, Höffler (2010) showed that spatial ability was important when working with visualizations, which suggests that verbal/visual cognitive style is an important learner characteristic.

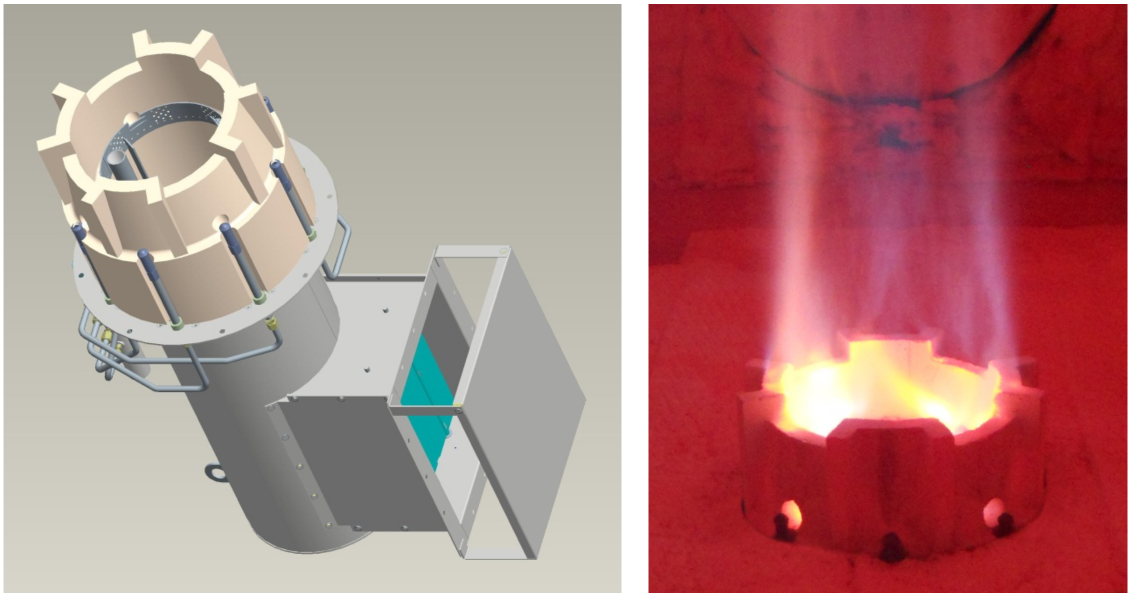
In general, learners typically will have lower prior knowledge of a subject they are studying which is normally the reason for education and training. However, many types of required training include refresher courses on a periodic basis. In that case, learners may have higher prior knowledge of the subject, but are still taking the training because it is mandatory. This suggests that refresher training may need to be designed differently to account for the higher prior knowledge of the learners.

Statement of the Problem

Engineers need to take continuing education courses that are frequently delivered online. However, those courses are often poorly designed and do not follow research-based recommendations for using multimedia effectively to enhance learning. No instructional design guidelines were found for designing effective distance courses specifically for working engineers. No previous research was found that studied the learning strategy preferences and the perceptual verbal-visual cognitive styles of working engineers. Therefore, the broader underlying problem for this study is a lack of current guidelines for developing distance continuing education content for working engineers. Instructional design should be continuously improved for both classroom and online courses (Herrington & Oliver, 2000). As stated by Sun and Cheng (2007), "How to develop a cost-effective multimedia instructional material according to the properties of instructional content is emerging as an important issue of e-learning. Unfortunately, there is a lack of extant literature to address this critical issue” (p. 663). However, the underlying problem of lack of instructional design guidelines is complex and multi-factored and must be addressed by research in numerous small steps. The specific problem addressed in this study is the lack of available information about the learning strategy preferences, verbal-visual cognitive styles, and multimedia preferences of working engineers. The lack of this information is problematic because it could be used for designing more effective asynchronous self-directed online course content, including multimedia, for working engineers.

This study’s problem is delimited by both its online context and its content. While most of the results of the research may also pertain to teaching engineers in the classroom, learners usually do not have direct control over the multimedia in the classroom as they do in online learning. For example, the instructor typically controls how videos and virtual reality simulations are displayed in the classroom, while the learner controls them in an online course.

The subject matter used in this investigation was the COOLstar™ burner (Chung, Meinen, Poe, Lewallen, Baukal, & Schnepper, 2005) shown in Figure 5. This burner produces very low pollutant emissions and superior performance compared to previous generations of technology. This design was used as the subject matter in this study because a significant portion of the subjects had substantial prior knowledge, while another portion did not. The typical condition for students in a formal learning context is that they generally do not know much about the subject matter, which is why they are taking the training. Having subjects with a range of prior knowledge was used in this study to determine if that variable has a significant influence on their multimedia preferences. The specific aspect of the subject matter used in this study was the major component parts of this burner. This type of explanatory representation is referred to as a *system topology* (Mayer & Gallini, 1990). This presentation forms the basis of more detailed training on this burner design as students need to know the major component parts before they learn about the operational principles.



(a) (b)

Figure 5. COOLstar burner: (a) drawing, (b) in operation.
Source: John Zink Company, LLC.

The content for this study's problem is of practical significance to engineering companies. Process burners (Platvoet & Baukal, 2013) are potentially dangerous pieces of equipment, consume large quantities of fuel, can generate large amounts of pollution emissions, and can cause significant business downtime if they are not properly maintained (Baukal, 2001). Failure to conduct this study might mean the fundamental principles in the online theory course would not be adequately learned, which could reduce learning in the face-to-face Fundamentals course. This could lead to safety concerns, reduced fuel efficiency, excessive pollution emissions, and unscheduled downtime. Those problems could cause damage to people and equipment, loss of valuable energy resources, harm to the environment, and loss of revenue.

Purpose of the Study

The purpose of this study was to describe (a) the learning strategy preferences, verbal-visual cognitive styles, and multimedia preferences of working engineers, and (b) the relationships among these variables and to selected demographic variables.

Research Questions

The following questions guided this study:

1. What is the learning strategy preference profile for working engineers?
2. How do the learning strategy preferences of working engineers compare to the norms for the general population?
3. What is the verbal-visual cognitive style profile for working engineers?
4. How do the verbal-visual cognitive styles of working engineers compare to:
    - 4.1 The norms for the general population?
    - 4.2 The norms for engineering students?
5. What are the multimedia preferences of working engineers?
    - 5.1 What are the verbal preferences of engineers?
    - 5.2 What are the static graphic preferences of engineers?
    - 5.3 What are the non-interactive dynamic graphic preferences of engineers?
    - 5.4 What are the interactive dynamic graphic preferences of engineers?
    - 5.5 What are the preferences of engineers among the multimedia types of verbal, static graphics, non-interactive dynamic graphics, and interactive dynamic graphics?
6. What are the relationships of engineers' learning strategy preferences to the demographic variables of gender, age, total engineering work experience, total engineering work experience at John Zink, management level at John Zink, highest engineering degree, specialty for highest engineering degree, professional engineering license, and prior knowledge of the topic?
7. What are the relationships of engineers' verbal-visual cognitive styles to the demographic variables of gender, age, total engineering work experience, total engineering work experience at John Zink, management level at John Zink, highest engineering degree,

specialty for highest engineering degree, professional engineering license, and prior knowledge of the topic?

8. What are the relationships of engineers' multimedia preferences to the demographic variables of gender, age, total engineering work experience, total engineering work experience at John Zink, management level at John Zink, highest engineering degree, specialty for highest engineering degree, professional engineering license, and prior knowledge of the topic?
9. What is the relationship between engineers' learning strategy preferences and their multimedia preferences?
10. What is the relationship between engineers' verbal-visual cognitive styles and multimedia preferences?
11. What is the relationship between engineers' learning strategy preferences and verbal-visual cognitive styles?

Definitions of Key Terms

Conceptual Definitions

Animation	Moving (dynamic) representation of simulated objects
Dynamic graphic	Moving image such as a video or animation
Dynamic media hypothesis	Proposition that learning is enhanced more by dynamic media than by static media
Interactive	User (e.g., learner) controls display of visuals
Learning strategy	"Learning strategies are the techniques or skills that an individual elects to use in order to accomplish a specific learning task. Learning strategies differ from learning style in that they are techniques rather than stable traits and they are selected for a specific task" (Conti & Fellenz, 1991, p. 1)
Multimedia	"Combination of multiple technical resources for the purpose of presenting information represented in multiple formats via multiple sensory modalities" (Schnotz & Lowe, 2003, p. 117).
Multimedia instruction	"Presentation of material using both words and pictures, with the intention of promoting learning" (Mayer, 2009, p. 3)
Static graphic	Fixed, non-moving image such as a photograph or drawing

Static media hypothesis	Proposition that learning is enhanced more by static media than by dynamic media
Video	Moving (dynamic) real representation of an object
Virtual reality	Controllable movable representation of an object or environment

Operational Definitions

Engager learning strategy preference	Subject selects *Engager* on ATLAS instrument
Engineer	As determined by the Human Resources department at John Zink Co. LLC based on education or equivalent experience
Learning strategy preference	Subject selects *Engager*, *Navigator*, or *Problem Solver* on ATLAS
Multimedia preference	Preference self-selected by subjects on researcher-developed survey
Navigator learning strategy preference	Subject selects *Navigator* on ATLAS instrument
Problem Solver learning strategy preference	Subject selects *Problem Solver* on ATLAS instrument
Significance level	$p \leq .05$ (95% confidence level)
Verbal cognitive style	Subject selects *Strongly more verbal than visual* or *Moderately more verbal than visual* on the Verbal-Visual Learning Style Rating
Visual cognitive style	Subject selects *Strongly more visual than verbal* or *Moderately more visual than verbal* on the Verbal-Visual Learning Style Rating
Visual-verbal cognitive style	Subject selects their style on the Verbal-Visual Learning Style Rating
Working engineer	Engineer employed full time (at least 32 hours/week)

Significance of the Study

Developing cost-effective multimedia instructional materials is emerging as an important issue in e-learning (Sun & Cheng, 2007). Furthermore, in-service training for employed engineers is increasingly being delivered via e-learning. Yet, there is a lack of extant literature to address this multimedia instructional design for e-learning. This study specifically addresses the lack of available information about the learning strategy preferences, verbal-visual cognitive styles, and multimedia preferences of working engineers. This information would be useful for designing more effective asynchronous self-directed online course content, including multimedia, for working engineers.

The results of this study will be used to design more effective online continuing engineering education courses. The U.S. National Academies of Science and Engineering recently funded a study which argued the importance of research-based instructional strategies for undergraduate science and engineering students (Singer, Nielsen, & Schweingruber, 2012). While that study was targeted at undergraduates, it applies equally well to those same students after they graduate. Because the existing research is inconclusive about which types of multimedia are most effective for learning, this research determined multimedia preferences for the study's population. The static and dynamic visuals used in the research were designed according to Mayer's Multimedia Design Principles, thus giving support from current multimedia theory and research.

Learner preferences give the instructional designer some guidance for what distribution of visuals should be used in a course. More research needs to be done on multimedia learning that focuses on factors that differentiate learners (Samaras, Giouvanakis, Bousiou, & Tarabanis, 2006), which is a key variable of this study where the differentiating factors among the participants were learning strategy preference, verbal-visual cognitive style, and learner demographics.

The problem studied here is primarily of interest to practitioners who design online courses. However, it should also be of interest to researchers as it provides additional information for further research on what type of online format may be preferable for a particular type of learner: employed engineers.

CHAPTER II

LITERATURE REVIEW

Introduction

According to Reigeluth (1983, p. 4), “Instructional design is a discipline that is concerned with understanding and improving one aspect of education: the process of instruction.” The present research was concerned with improving the instructional design of continuing engineering education distance courses, although the information would be useful for designing any type of continuing engineering education courses. Sambrook’s (2001) research study assessed the importance of a variety of factors on learners’ perceptions of the quality of computer-based learning materials. Two of the top factors out of the 33 identified included the graphics (number and quality of pictures and diagrams) and text (amount and balance with graphics). These preferences were both considered in this study for the narrow group of learners which comprised a specific set of adult learners: working engineers.

The literature reported in this chapter covers aspects of engineering education, multimedia, and learner differences relevant to this study.

Engineering Education

Calls continue to be made for improving engineering education. As the 21st century opened, the U.S. National Academy of Engineering established a Committee on Engineering Education to answer the question "What will or should engineering be like in 2020?" (National Academy of Engineering, 2004). The Phase 2 report from that committee titled *Educating the Engineer of 2020* (National Academy of Engineering, 2005) called for the reinvention of engineering education. An important finding of that study was the importance of addressing *how* students learn in addition to *what* they learn and called for more research into engineering education. This includes how to better serve students with different learning styles and how to determine pedagogical approaches that excite and motivate them. The *Journal of Engineering Education* recommended further research on how engineering learners develop knowledge (Anonymous, 2006). Duderstad (2008, p. v) recommended "a systematic, research-based approach to innovation and continuous improvement of engineering education." The U.S. National Academy of Engineering (2008) identified 14 grand challenges in engineering. One of these was to advance personalized learning that recognizes individual preferences and aptitudes to help motivate learners to become more self-directed. While that challenge was targeted at the development of learning software by computer engineers, it can be applied to all types of learning and learners, including all types of engineers.

One way to address individual differences in how students learn and to personalize learning options is through the concept of learning style. *Learning style*, also referred to as *psychological type* (Jung, 1971; McCaulley, 1976; McCaulley, Godleski, Yokomoto, Harrisberger, & Sloan, 1983), refers to how students preferentially perceive (e.g., sensory vs. intuitive), how information is most effectively perceived (e.g., verbally or visually), how information is preferentially organized (e.g., inductive vs. deductive), how information is processed (e.g., actively vs. reflectively), and how understanding progresses (e.g., sequentially vs.

globally) (Felder & Silverman, 1988). These styles are relatively stable and concern cognitive, affective, and psychological behaviors related to how learners perceive, interact with, and respond to a learning environment (Felder & Brent, 2005). Numerous previous studies have considered learning styles for engineering students (Baukal, Ausburn, Mattson, & Price, 2013), but none were found for working engineers.

Interactive multimedia can be defined as “an exchange between the viewer and the media as well as more than a single medium” (Misovich, Katrichis, Demers, & Sanders, 2003, p. 1). Wiesner and Lan (2008) argued that passive and interactive multimedia instruction is one of the important ways of improving engineering education. Some of the benefits they identified for interactive multimedia included enhancing student engagement; helping students focus on and understand key concepts; giving students as much time as needed to view information, answer questions, and review; and giving students the privacy to make mistakes and go at a slow pace if they need to.

Continuing Engineering Education

Professions such as law, medicine, and engineering are often characterized by “rigorous professional knowledge” (Schön, 1987, p. 3) that changes, sometimes rapidly, with time. Lifelong learning is required to maintain proficiency and in many cases licensure (Baukal, 2012; Bennett & LeGrand, 1990). Learning may be informal or formal where informal is usually done without an instructor while formal usually includes an instructor. Examples of informal learning, sometimes referred to as *workplace learning* (Malloch, Cairns, Evans, & O’Connor, 2011), include reading trade magazines and journals and searching the Internet. Formal learning includes taking classes that may be either for-credit or not-for-credit. The “classes” also include one-on-one on-the-job mentoring by more experienced colleagues.

The Institute of Continuing Professional Development (ICPD, 2011) defined continuing professional development (CPD) as "the systematic maintenance and improvement of knowledge, skills and competence, and the enhancement of learning, undertaken by an individual throughout his or her working life." The on-going education of professionals sets them apart from other jobs, leading to elevated status and prestige. This dynamic process is called *professionalization* where professionals continuously upgrade their knowledge and skills (Houle, 1980). Continuing education includes "all those processes that contribute to the advancement of an individual's knowledge, skill, understanding, competence, and general professional and personal development" (Padfield & Schaufelberger, 1998, p. 8). Continuing education, CPD, and professional development are all related terms that generally concern learning outside the normal workplace (Dirkx, 2011).

Training can be defined as "a planned effort by a company to facilitate employees' learning of job-related competencies" where the competencies include "knowledge, skills, or behaviors that are critical for successful job performance" (Noe, 2005, p. 3). The continuing education and training of engineers is of specific interest here.

Engineering can be defined as "the field or discipline, practice, profession and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purposes" (Marjoram & Zhong, 2010). The National Science Foundation (1977, p. 1) defined continuing engineering education and its characteristics as:

- the substantive content deals with engineering knowledge,
- taken after initial employment,
- addresses updating and diversification rather than advanced education,
- is structured, goal oriented, and intentional, and

- has a duration adequate for a significant increment of training.

Saline (1983, p. 123) defined CEE as “professional technical or management education taken in relatively small doses throughout a career.”

Many institutions have identified the importance of CEE. A number of U.K. government agencies have recommended CEE (Galloway, 1998). The European Society for Engineering Education sponsored a report which argued action is needed to improve the continuing education of engineers (Padfield & Schaugelberger, 1998). A report by the U.S. National Academy of Engineering (2005) recommended that engineering institutions teach students how to be lifelong learners. The American Society of Mechanical Engineers’ 2028 Vision included lifelong learning as one of the four areas for focused improvement (ASME, 2008). The U.S. National Academy of Engineering (2008) identified 14 grand challenges for engineering, many of which will require CEE as some of the subjects (e.g., prevent nuclear terror) are not typically covered in university education. “To successfully integrate process and knowledge, engineers must not only stay informed about new and emerging technologies but also be aware of knowledge and skills from other domains” (Sheppard, Macatangay, Colby, & Sullivan, 2009, p. 6). A comprehensive report sponsored by UNESCO (2010) on engineering also emphasized the need for CEE (Jones, 2010, p. 329):

> With the huge explosion of knowledge, engineers have been forced to become more specialized in their professional skills, which in turn forces judicious choices to be made in the topics taught during an initial education. The only way by which the tussle between breadth and depth can be reconciled is the recognition that a first degree provides just an initial education and that Continuing Engineering Education (CEE) or Continuing Professional Development (CPD) is essential.

A report sponsored by the U.S. National Academy of Engineering argued that lifelong learning for engineers is imperative for sustaining American competitiveness in the 21st century (Dutta, Patil, & Porter, 2012). The most recent accreditation requirements for engineering programs include an outcome that students are expected to achieve at the completion of their degree, "a recognition of the need for, and an ability to engage in life-long learning" (Engineering Accreditation Commission, 2012, p. 3).

The demand for CEE continues to increase. There are many reasons for this including rapid technological advances, globalization, increasing environmental emphasis, and sociopolitical changes. Technical obsolescence (Ovesen, 1980) is a continuing problem due to the ever-increasing pace of changes in technology. Failure to continually learn after receiving an engineering degree leads to obsolescence because of the rapid changes in technology (Barton & Bommer, 1992). For example, the fields of nanotechnology and biotechnology are changing so rapidly that continuous training is required to maintain proficiency in those fields. As technology continuously changes engineering, CEE improves job performance and usually leads to increased compensation (Morris, 1978). It is recommended for quality assurance in a profession and in some cases it may be mandated to maintain licensure (Jeris, 2010). Licensure is particularly important in civil engineering because of the many public works projects done for governments. Some argue that CEE is critical to enhancing the innovation (Keating, Stanford, Dunlap, Aherne, & Mendelson, 2001) that keeps a professional field viable and its workforce effective and competitive.

Engineers participate in many types of continuing education, including both informal and formal training (Cervero, Miller, & Dimmock, 1986). Informal training is generally unplanned and initiated by the individual, although it could include sanctioned learning such as mentoring, coaching, and special assignments. For example, reading journals and magazines and attending conferences helps keep engineers current with changes in technology. Formal training is "planned learning activities that are intended to help individuals acquire specific areas of knowledge, awareness, and skills" and "mostly involves institutionally sponsored and endorsed programs, which would include almost all training and development programs that organizations offer" (Jacobs & Park, 2009, p. 140). Engineers may also take formal classes with instructors that may be for credit and possibly even leading to an advanced degree. Formal professional development not leading to a degree is the specific focus for the study reported here.

The challenge is how to deliver CEE when and where it is needed, at a reasonable cost. Continuing education must be relevant and should be designed to solve industrial problems (Weimar, 1992). Continuing professional education (CPE) must be related to professional practice to help professionals make decisions about situations they encounter (Cervero, 1992).

Employer-sponsored CPE dwarfs that offered by any other type of provider and possibly accounts for more than all other providers combined (Cervero, 2001). While much has been written, for example, on CPE offered by universities, relatively little has been written about employer-sponsored CPE (Baukal, 2012) despite its prominence in workforce education and training.

CEE courses include all types of technical (e.g. equipment, processes, software), management (e.g. leadership, employment law, and enhancing team performance), and soft skills (e.g. communication and presentation skills) courses. CEE courses combining engineering and management are the most popular types of courses (Beruvides & Ng, 2009). Cole, Moss, Gohs, Lacefield, Barfield, and Blythe (1984) broadly defined four categories of continuing education courses for engineers:

1. remediating and upgrading basic technical knowledge and skills,
2. extending and broadening previously-learned scientific and technical skills,
3. learning new concepts and skills to keep up with technology advancements, and
4. learning new knowledge and skills outside engineering.

CEE is one of the most efficient ways to transfer technology and improve productivity (Markkula, 1985). Besides facilitating maintenance of proficiency, CEE allows engineers to learn about new technologies, whether in their own organization or in others. This might be in the form of traditional classroom instruction, by reading trade journals, or by attending conferences. Productivity can be improved by applying new technologies or taking advantage of existing technologies, processes, or procedures that were not previously used.

There are some specific challenges unique to CEE. Continuing professional development is particularly important for engineers, compared to other professions, because of the rapid changes in technology (Evetts, 1998). The half-life of knowledge is the time it takes for half of one's knowledge to become obsolete. In some engineering fields, the half-life has become so short, due to rapid changes in technology, that some information is becoming obsolete even before completing an undergraduate education (Wulf & Fisher, 2002). However, it should be noted that the basics taught in many college engineering courses, such as the First Law of Thermodynamics, do not change with time.

Another unique challenge is globalization. New technology is being developed all over the world. It is no longer sufficient to keep up with advancements in one's own country. Today's engineers must be familiar with and be able to apply new technologies developed on a global scale. It is not practical for engineers to travel all over the world to learn about the latest advancements, which is one reason why distance CEE is so important.

Learning new technologies can often be more challenging because of the need to use multiple senses to fully understand them. In some cases, this may mean hands-on instruction where students actually manipulate the new technology. For example, learning how to program a controller to automatically adjust a flow rate may require students to actually use the controller. In other cases, instruction may need advanced visualization and animation to aid in understanding the technology. This challenge is not usually faced by, for example, accountants or attorneys learning the latest developments in their fields. Bork (2004) believed computer-based distance education is the best way to provide continuing education on a global basis. Industry has been a leader in using media-based continuing engineering education (Biedenbach, 1978).

Distance Learning

In the traditional classroom, a teacher is physically present. In contrast, distance education refers to instruction where the student and instructor are separated by distance. Today's distance learning via the Internet is much more effective than previous generations of distance learning, such as by mail correspondence, radio broadcast, or satellite transmission, because of the rapid expansion of bandwidth which allows smooth playback of electronic learning content (Passerini & Granger, 2000) at real-time speed with modest transmission costs and multiple media alternatives.

Simonson, Smaldino, Albright, and Zvacek (2012, p. 7) defined distance education as, "institution-based, formal education where the learning group is separated, and where telecommunications systems are used to connect learners, resources, and instructors." Distance education can be synchronous where the student is learning from an instructor in real time (e.g., teleconferencing). It can also be asynchronous where students access the instructional material at a time convenient to them (e.g., viewing videotaped lectures) when the instructor may or may not be available. A specific type of distance education is *e-learning*, sometimes called computer-based training (CBT), online learning, distributed learning, and web-based training, which can be defined as "the use of computer network technology, primarily over an intranet or through the Internet, to deliver information and instruction to individuals" (Welsh, Wanberg, Brown, & Simmering, 2003, p. 246). As an example, the John Zink Institute offers an asynchronous online course on process burner theory (Baukal, 2008).

Many studies have shown there is little if any difference in learning between distance and face-to-face courses (e.g., Allen, Bourhis, Burrell, & Mabry, 2002; Allen, Mabry, Mattrey, Bourhis, Titsworth, & Burrell, 2006; Jensen, 2011; Watkins, 2010; Wisher & Curnow, 2003). In some cases, while there was no observed difference in learning, online courses were more time- and cost-efficient (Schmeeckle, 2003). In some cases, distance learning students outperformed traditionally-instructed students (e.g., Means, Toyama, Murphy, Bakia, & Jones, 2010; Shachar & Neumann, 2003).

Many potential benefits of distance education have been cited, including (Moore & Kearsley, 2005, pp. 8-9):

- increasing access to learning and training opportunities,
- providing opportunities for updating skills,
- improving cost effectiveness of educational resources,
- expanding capacity for education in new subject areas, and
- offering a combination of education with work and family life.

Muench (2006) added some other benefits:

- greater schedule and learning flexibility,
- more frequent and timely updating of skills and knowledge, and
- highly focused learning.

Other advantages of e-learning are:

- consistency where the same message is delivered each time in any location (Bondarouk & Ruel, 2010),
- improved tracking and documentation of what training learners have completed (Welsh et al., 2003),
- greater learner autonomy (Tallent-Runnels, Thomas, Lan, Cooper, Ahern, Shaw, & Lu, 2006),
- improved access for individuals with disabilities who may have limited access and ability to attend traditional classroom training (Peel & Quayle, 2001), and

- supplementation for traditional face-to-face (F2F) courses (Baukal, 2008).

Klus (1995, p. 155) wrote, “The rapidity of technology transfer needed by companies to remain competitive requires the use of tools and ‘continuing education on demand,’ commonly understood in the inventory world as ‘just-in-time education.’” The only realistic way this can be consistently and rapidly provided is with distance education (Paton, 2002). A fundamental criterion of lifelong learning is that students can learn at their convenience (Burns & Chisholm, 2003). This requirement can often best be satisfied with distance education.

Another potential benefit of distance learning, compared to a conventional classroom, is that materials can be customized and adapted to individual learners through the use of the computer (Teixeira ,Teixeira, Pile, & Durão, 1998). Customized instruction is much more difficult in a classroom setting, unless the class size is very small.

Travel and living expenses for training in other cities can be saved through distance learning. Distance courses can often be completed at individual students’ convenience and are usually much less disruptive to the business compared to sending employees away for several days or more.

Despite its numerous benefits, there are also some potential challenges with distance education compared to traditional classroom courses. These include, for example: delayed response (for asynchronous courses), more difficulties in collaboration, increased distance between participants, computer technology problems, and lack of visual cues. Visual appeal is also important for motivating students (Yacovelli, 2012). Increased motivation is directly correlated to increased participation in e-learning (Garavan, Carbery, O’Malley, & O’Donnell, 2010).

There are some specific challenges that are somewhat unique to distance CEE, compared to CEE delivered F2F. These challenges include the need for hands-on learning, computationally-intensive demonstrations, complex and dynamic topics, and globalization. Walkington, Pemberton, and Eastwell (1994) argued that hands-on experience, including labs, is critical to the development of an engineer and must be included in any distance education engineering program. They suggested several possible solutions for labs for distance students, including having students do some lab work at their employer's facilities. Regarding the need for significant computing power to run computationally-intensive software, one researcher predicted that within a decade, computing power will probably not be a problem for even the most computationally-intensive programs today. Many topics in engineering are dynamic and three-dimensional, which creates a great challenge for distance CEE. One solution is computer-aided learning where students can interactively use sophisticated graphical software with animation capability (Ferguson, 1998). This gives students the flexibility to explore on their own to both enhance understanding and satisfy personal interests. Globalization requires engineers to work together with engineers in other parts of the world (Prados, Peterson, & Lattuca, 2005). Because of differences in time zones, languages, and cultures, this can be difficult. CEE that fosters globalization would be greatly beneficial to many engineers. As an example, Herder, Subrahmanian, Talukdar, Turk, and Westerberg (2002) described an engineering design course that was taught asynchronously at Carnegie Mellon University in the U.S. and at Delft University of Technology in The Netherlands. Part of the course involved multinational groups working together on projects, which students felt was an important course component. Asynchronous instruction was important because of the significant time zone differences between the U.S. and Europe.

The use of multimedia can significantly improve distance learning materials. Buckley and Smith (2008, p. 65) wrote, "Multimedia, in conjunction with traditional teaching materials, enhances the educational experience for online students by offering a variety of ways in which to learn and interact with content." Following proper instructional design guidelines is important when using multimedia in online training (Bedwell & Salas, 2010). Helping develop those guidelines was an important objective of the present research.

Distance Engineering Education

Relatively little research has been conducted on distance CPD (Donavant, 2009). This section of the literature review specifically considers the CPD of engineers who are working full time, usually in industry. The CEE courses considered here concern working engineers and are not for college credit. When compared to credit-based courses, CEE courses are generally shorter in duration, are targeted to specific professional applications, and are usually designed for rapid learning transfer.

College engineering courses are generally theoretical in nature, because it would be impossible to teach all the specific applications in a given field. For example, engineers may study fluid flow through pipes, but not typically how to design the valves that control the flow. Gräfen (1991) referred to the former as basic knowledge and the latter as specialized knowledge. While theory is not bad, CEE must be practical and is becoming more competency- and skill-based (Eydgahi & Eidgahy, 2000). Engineers taking CEE courses are typically mature professionals looking for information and skills they can apply in their jobs.

There are generally three types of learning during an engineer's career (National Research Council, 1985): on-the-job, informal learning (e.g., reading journals, attending technical meetings), and formal education and training which is of interest in the present study.

Cervero (2000) noted four important trends concerning continuing professional education in the 1990s:

1. The amount of continuing education offered at the workplace dwarfs that offered by any other type of provider, and surpasses that of all other providers combined.

2. Universities and professional associations are active and important providers, with an increasing number of programs being offered in distance education formats.
3. Universities are more actively collaborating with employers.
4. Continuing education is being used more frequently to regulate professionals' practice.

Weimar (1992, p. 386) made the following assertions regarding CEE:

1. Keeping technical and professional people up to date is a problem to industry and to the professionals themselves.
2. The problem is both a training and education problem and an information provision problem.
3. Universities are qualified to provide some of the training and information required. However, universities may not always be the most qualified and capable sources of education.
4. In those situations where continuing education programs offer the best solution they should be supported and exploited. Where continuing education is not naturally workable within the university structure, other solutions should be supported and exploited.
5. The solution to the need for keeping technical professionals up to date is complex and involves making use of a variety of education and information options. The problem should be attacked on its merits and indicated solutions rather than trying to impose a single generalized European solution prematurely.
6. Distance CEE allows unemployed engineers to improve their skills and marketability at home and at a reasonable cost. It also allows employed engineers to learn the basics of a new technology before attending a traditional classroom (Puttré, 1994).

Aided by the numerous benefits listed above, delivery of CEE content via distance education continues to grow in importance (Jones, 2003).

Distance education can be facilitated and improved by the use of multimedia, which relates multimedia and media-based instructional design directly to distance teaching and learning. However, while many multimedia tools are available to instructional designers of distance courses, those tools by themselves will not enhance learning or performance (Watkins, 2010). The proper multimedia should be selected based on sound research. This is the subject of the present research.

Engineering Visual Representations

Multimedia creation relies on various types of representations. *Representations* refer to things that we can see, hear, or touch (Tang, 2013). Representations can be categorized into descriptive (e.g., text) and depictive (e.g., graphics); representations may also be categorized as external or visual (anything that can be seen) and internal or mental (something in the mind) (Schnotz, 2002). Visual representations are restricted to things that humans can see and come in many forms including text, symbols, equations, lists, tables, spreadsheets, maps, charts, graphs, drawings, photographs, animations, videos, and virtual reality simulations. The term *inscription* is sometimes used to represent visual (external) representations that exist in material form, such as on paper or on a computer screen (Roth & McGinn, 1998), to distinguish them from mental (internal) representations (Pavio, 1986). Technical representations are particularly important in mathematics, science, and engineering for communicating information (Greeno & Hall, 1997; Singer, Nielsen, & Schweingruber, 2012). In the research presented here, representations that can be touched are specifically excluded as hands-on learning is not generally possible by distance learning.

Carter (2002) discussed an overall framework for developing multimedia systems for engineering education, although no specific recommendations were given on what types of multimedia should be used. There have been research studies investigating the use of multimedia in teaching engineering students, although none were found specifically related to teaching working engineers. Some examples will illustrate these studies. Daily (1994) called for the increased use of multimedia in educating engineering students and experimentally showed it was at least as effective, and in some cases more effective, than traditional teaching methods. Chang, McCuen, and Sircar (1995) recommended that interactive multimedia should be an integral part of engineering curricula. Reuther and Meyer (2002) experimentally showed that engineering students' enthusiasm towards multimedia was a function of their Myers-Briggs personality type. Höhne and Henkel (2004) recommended the use of multimedia in engineering design education. Istanbullu and Güler (2004) discussed the development of an online course incorporating multimedia for instruction concerning medical instrumentation for biomedical engineering students. Klemeš, Kravanja, Varbanov, and Lam (2013) described the use of multimedia to teach energy and process integration in university engineering programs.

Lesh and Doerr (2003) presented a conceptual schematic for solving mathematical problems using a variety of interrelated representations as shown in Figure 6.

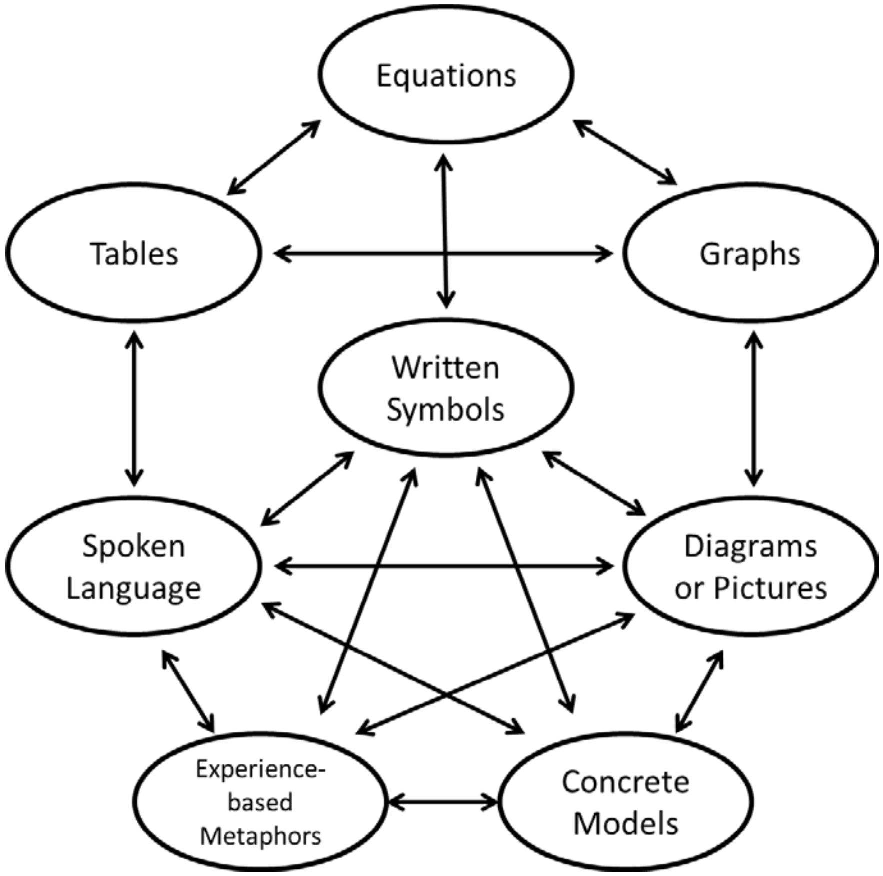


Figure 6. Conceptual model for solving mathematical problems using interrelated representations (Lesh & Doerr, 2003).

The Lesh Translation Model (LTM), shown in Figure 7, is a framework used to show the interactions (translations) between various types of representations of a concept (Moore, Miller, Lesh, & Stohlmann, 2013).

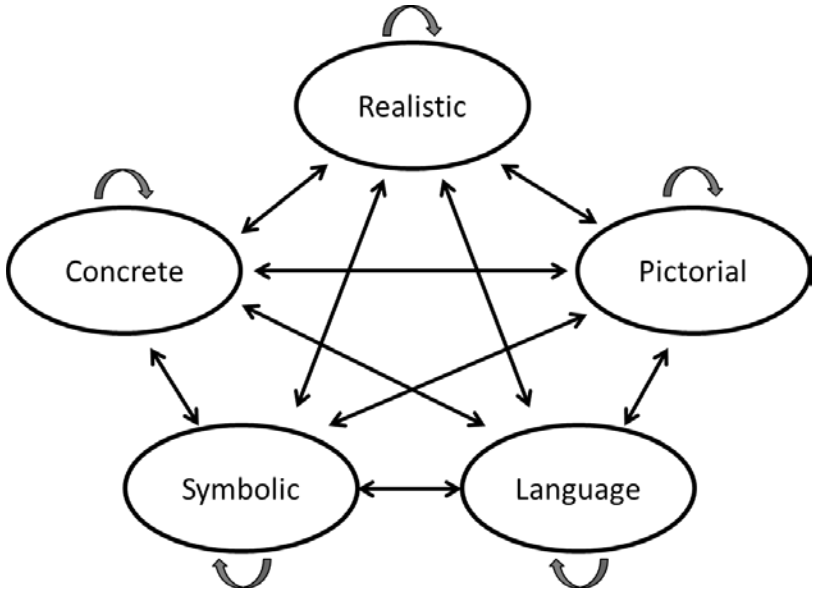


Figure 7. Lesh Translation Model (Moore, Miller, Lesh, & Stohlmann, 2013).

Johri and Lohani (2011, p. 958) wrote, “Representations such as free-body and circuit diagrams are central to engineering practice and proficiency. . . . The engineering profession – including its teaching, learning, and practice – is centered on the creation and transformation of representations.” In the introduction to a recent special issue of the *Journal of Engineering Education* on representations in engineering, Johri, Roth, and Olds (2013) argued that representations are the foundation of design and yet their use in engineering learning is understudied, particularly as it pertains to theory building and the application of theories. Juhl and Lindegaard (2013) experimentally showed how representations, which they referred to as *nonhuman actors*, are used by engineering students not only to communicate information but also play a crucial role as mediators in multidisciplinary projects to help create designs in a process they referred to as *collaborative design synthesis*. Diefes-Dux, Hjalmarson, and Zawojewski (2013) recommended that instructors study the representations created by their engineering students to help improve instructional design and practices. Moore et al. (2013) showed that teams of engineering students need fluency in developing representations to develop models.

McGrath and Brown (2005) advocated for more visual learning in undergraduate engineering education. These examples represent strong support for representations in engineering education.

Virtual reality (VR) is a relatively new type of visual representation that can be very effective in learning contexts. For example, Chen (2006) found that learning was significantly improved with VR compared to learning without VR where the topic was traffic rules and regulations. Pantelidis (1997) discussed many reasons for using VR specifically in engineering education. Some important reasons of interest in this study included: motivating students, the capability of zooming into an object, allowing learners to proceed at their own pace, and requiring the learner to interact with the medium. VR can be especially powerful in situations where danger may be involved, such as operating a process burner (Platvoet & Baukal, 2013), where learners can safely make mistakes in the VR environment without anyone getting hurt or any equipment being damaged (Winn & Jackson, 1999). VR is expected to be a common tool on the desk of most engineers in the near future (Vance, 2013), which opens the door for its use as a tool for distance education.

Multimedia

Multimedia instruction can be defined as "the presentation of material using both words and pictures, with the intention of promoting learning" (Mayer, 2009, p. 5). Multimedia can refer to (a) *sensory modalities* such as text vs. narration, (b) *representational modes* such as graphics vs. text, or (c) *delivery media* such as paper vs. computer (Mayer & Moreno, 2002).

According to the *multimedia principle*, learners learn better from words and pictures than from words alone (Fletcher & Tobias, 2005; Mayer, 2001, 2009). A considerable body of research literature supports this principle. For example, Levie and Lentz (1982) did a meta-analysis of 155 experimental comparisons and found learning was consistently better for text plus static graphics compared to text alone. However, there is some debate about the efficacy of media for enhancing learning. This was prominently debated by Clark (Clark, 1983, 1994; Clark & Salomon, 1986) who argued media will never influence learning and Kozma (1991, 1994) who argued media can influence learning. A mediating position was taken by Samaras, Giouvanakis, Bousiou, and Tarabanis (2006) who argued that media has the *potential* to enhance learning, but only if it is properly designed. However, media that is improperly designed can actually inhibit learning. Further complicating the situation, certain multimedia (i.e., media combinations) may be more effective in certain types of learning contexts but not in others. For example, the choice of multimedia has been empirically demonstrated to be critical for learning complex procedural tasks, but not for simple ones (Bhowmick, Khasawneh, Bowling, Gramopadhye, & Melloy, 2007). Another example is from the study by Macaulay and Pantazi (2006) who found multimedia enhanced learning compared to text only when the material was very difficult, but found no significant differences when the material was less difficult.

Not all forms of multimedia are equally preferred in instructional settings. Some examples will illustrate this. Hays (1996) showed that animations were superior to text in terms of learning performance for topics related to time and motion. Chuang (1999) found that learning was better with animation plus text plus narration, compared to animation plus voice and animation plus text, for seventh graders studying physics. Baker and Dwyer (2000) showed in a meta-analysis that visual media were more effective than purely verbal media for learning performance. Yang, Andre, and Greenbowe (2003) found that animations were more effective for learning chemistry compared to using still photographs. Christie and Collyer (2008) showed experimentally that video with audio was superior for learning compared to audio only. One of Park and Etgen's (2000) multimedia instructional design principles is that properly combined media types are more effective than individual media types. Based on findings such as those reported here have led many media design specialists to conclude that properly designed multimedia can effectively motivate learners and has the potential to enhance learning (Gulbahar & Yildirim, 2006; Leontidis, Halatasis, & Grigoriadou, 2011).

Dale's Cone of Experience

Edgar Dale (1946, 1954, 1969) wrote a textbook on using "audiovisuals" (as they were called at the time) in teaching which had three editions spanning over 23 years. The book was targeted towards K-12 teachers. Chapter four of each edition was titled "The Cone of Experience" which discussed a range of learning experience possibilities. Dale's Cone of Experience (CoE) is considered an icon in educational media (Subramony, 2003) that has widely influenced the use of instructional media (Counts, 2004). Ely (1970, p. 84) wrote that Dale's CoE "has probably had more influence on the philosophical-psychological underpinnings in the field than any other conceptual schema."

There is no mention of any theoretical basis for the CoE in the first two editions of Dale's influential book; Dale himself wrote (1946, p. 37; 1954, p. 42), referring to the cone, "It is merely a visual aid to explain the inter-relationships of the various types of audio-visual materials, as well as their individual positions in the learning process." However, the theory stance changed in the third edition of the book. According to Dale's third edition (1969), the cone was based on the three major modes of learning as developed by Bruner (1966): the enactive mode (direct experience), the iconic mode (pictorial experience), and the symbolic mode (highly abstract experience). Although Dale referenced Bruner's 1966 book, Bruner's theory actually originated in an earlier paper (Bruner, 1964). Dale also mentioned John Dewey frequently in the third edition. Dale was heavily influenced by Dewey's belief in the importance of *experience* in learning (De Vaney & Butler, 1996). According to Eastmond and Bentley (2005, p. 108), Dale's cone "is essentially a visual representation of Dewey's approach." However, despite the influences of others, Dale's original cone of experience had no theoretical or experimental basis (Dwyer, 2010).

Later interpretations of Dale's cone have argued in favor of a stronger theoretical basis in the work of Jean Piaget on human cognitive development and the construct of concrete vs.abstract reasoning. Dale referenced Piaget as follows (1969, p. 6), "Jean Piaget, the distinguished Swiss psychologist, has said that the more a child has seen and heard the more he wants to see and hear. Experience begets experience. Intelligence is not only something you are born with; it is also learned." While Dale did not directly link Piaget with his cone of experience, others (e.g., Arendale, 1993; L. J. Ausburn & Ausburn, 2008) have done so because Piaget's well known theory of cognitive development distinguishes between concrete and abstract reasoning during learning.

Piaget was a Swiss psychologist who proposed a human cognitive development model consisting of four stages with the approximate age range given in parentheses: sensorimotor (0-2), preoperational (2-7), concrete (7-12), and formal (12-adulthood) (Piaget & Inhelder, 1969). While the age ranges for the four cognitive development stages are approximate, the order is fixed and sequential according to Piaget. The sensorimotor stage is where intelligence is based on perceptual experiences. The preoperational stage is the start of a sophisticated language system, egocentric reasoning, and perception-bound thinking. The concrete operational stage is characterized by the development of reversible thought, logical operations, the ability to solve concrete problems, and experience-based thinking. The formal operational stage includes the formulation and testing of hypotheses, abstract thought, hypothetical-deductive reasoning, and thought that is no longer bound by perception.

The last two stages are of particular interest here. The concrete operational stage is where children are still primarily limited to concepts with which they have direct experience (Pulaski, 1971). They have the ability to apply logical thought to concrete problems (Wadsworth, 1996). They have difficulty with abstract concepts such as the use of symbols. In the formal operational stage, thinking is no longer bound to direct experience and can include abstraction such as the use of symbols and hypothetical propositions (Ginsburg & Opper, 1988).

Piaget's theory has profound implications for education including how to teach children at various stages of development which are loosely associated with their age. Although Piaget was not specifically concerned with the educational implications of his theory (Jacob, 1984), others have suggested that one obvious recommendation based on his theory would be that learning materials should be consistent with a child's stage of cognitive development (e.g., Brainerd, 1978). Learners unfamiliar with a topic should start with the more concrete before progressing to the more abstract (Kamii, 1973). With reference to Piaget's theory, Singer and Revenson (1978, p. 17) wrote, "All children must be able to understand the world in concrete terms before they can begin to think in the abstract." This is supported by brain research where the strongest links in learning are usually made through concrete experience (Wolfe, 2010). In terms of the CoE, the audiovisual used in a learning context should be consistent with the learner's knowledge level of the particular subject (Dale, 1969).

Dale's CoE shows the level of abstraction for various types of learning activities to help educators design appropriate instructional materials using audiovisuals. One common misconception is that more concrete is better than more abstract (Simonson, Smaldino, Albright, & Zvacek, 2012). This is sometimes referred to as the *realism theory* where more realistic learning experiences are preferred (Doo, 2005). In actuality, the truth is not so simple. In some learning contexts, more direct interaction may indeed be needed, such as when the learner has no previous experience or foundation with a subject (Weston & Cranton, 1986). In other learning contexts, symbolic expression may be preferred, such as when a graduate chemistry student no longer needs direct experience or even words and uses the symbol CO_2 instead of the words *carbon dioxide*. As an instructional design strategy, some recommend going from more concrete to more abstract (Svinicki & McKeachie, 2011), which would include a range of techniques from Dale's Cone.

Gagné and Briggs (1974, p. 151) suggested the following rule concerning Dale's Cone: "Go as low on the scale as you need to in order to insure learning, but go as high as you can for the most efficient learning." Both the learner and the learning objective need to be considered in the choice of what level to use on Dale's Cone (Briggs & Wager, 1981).

There are two principal reasons why Dale's Cone of Experience needed to be updated for the research conducted here. The first is that the CoE was originally developed primarily for K-12 education. The present research concerns the continuing education of working engineers who are adults. Some of the forms of audiovisual listed in the CoE are not particularly relevant to adult learners in the workplace. For example, study trips, exhibits, and educational television are not likely to be used in workforce development.

The second major reason for updating the CoE is that some current forms of multimedia were not readily available to teachers and instructional designers when Dale proposed his CoE. For example, virtual reality (VR) is a relatively new element of multimedia available to educators today which has the potential to show very realistic simulations of things like airplane cockpits and operating rooms (F. B. Ausburn & Ausburn, 2008). While other forms of multimedia, such as videos and animations, were available when Dale developed the CoE, they were not very feasible for most teachers to use at the time. Today, the lower cost and ubiquitous availability of both hardware and software make these readily available to most teachers in the Western world.

Seels (1997, p. 358), who was mentored by Dale, wrote, "While the direct to vicarious and purely symbolic experience continuum is still valid, the cone is dated in its description of media." According to Richey, Klein, and Tracey (2011, p. 86), "One could easily update the Cone by substituting modern technology." That is what has been done by this researcher for the present study.

The proposed Multimedia Cone of Abstraction (MCoA) shown in Figure 3 is in some ways simpler than Dale's Cone, but in other ways much more complicated. The proposed MCoA has a much stronger theoretical foundation (Baukal, Ausburn, & Ausburn, 2013). While many have mistakenly generically attributed more worth to more concrete learning materials and less worth to more abstract materials, neither Dale's CoA nor the proposed MCoA intend to rank levels. In some learning contexts, more concrete materials may be more appropriate (e.g., with novice learners) while in other contexts more abstract materials may be preferred (e.g., with expert learners). This is a primary job of the instructor to determine what level of abstraction is best for their learners and the specific learning context.

Learning with Multimedia

The focus of this study is the use of multimedia in online learning. However, the results would be generally applicable to any type of learning, where the main limitation is that hands-on learning was specifically excluded from the present study. A primary concern is the effect of multimedia on learning. Research has demonstrated that multimedia can enhance learning in online courses. For example, Kekkonen-Moneta and Moneta (2002) found that online students performed as well as classroom students in an introductory computer course where multimedia was incorporated into the online version of the course. Aly, Elen, and Willems (2004) experimentally determined that an online instructional program incorporating multimedia was as effective as traditional lectures for undergraduate training in orthodontics. Backer (2005) showed experimentally that students taking a technology and civilization hybrid (online plus classroom) course with multimedia performed as well as or better than students taking the same course in a traditional classroom. Stephenson, Brown, and Griffin (2008) found that students using online modules incorporating multimedia outperformed students taking traditional lectures on human genetics.

While multimedia can be effective, not all forms of multimedia are equally preferred in instructional settings. It is often naturally assumed that dynamic (moving) visuals such as videos and animations are superior to static (still) visuals such as photographs and drawings (i.e., the *dynamic media hypothesis*) because of their ability to show temporal relationships (Hegarty, 2004; Lowe, 1999). The transient nature of dynamic visuals can help learners develop dynamic mental models (Kozma, 1991). Many studies have found that students prefer dynamic over static visuals (e.g., Smith & Woody, 2000), and a slight but statistically significant improvement in learning has been documented (e.g., Rieber, 1991). Baek and Layne (1988) found performance ranged from highest to lowest for students viewing presentations with: (1) animations, (2) static graphics, and (3) text only. Höffler and Leutner (2007) did a meta-analysis of 26 primary studies that compared dynamic and static visualizations and found a statistically significant advantage for animations over static pictures. Lin and Dwyer (2010) found a statistically significant learning advantage measured with four different types of tests for students viewing animations compared to those viewing static pictures. These are examples of studies that showed learning superiority of dynamic over static visuals.

However, many studies have shown no difference in learning using multimedia compared to not using multimedia (e.g., Lewalter, 2003; Narayanan & Hegarty, 2002). For example, Shih and Alessi (1996) found no difference in learning for content presented in text only, voice only, and text plus voice. Similarly, Gallegos-Butters and Schneider (2004) found no significant differences in learning between text and narration. In an example involving an online learning environment, Doo (2005) experimentally compared learners' reactions, cognitive retention of learning content, and behavioral reproduction for text only, audio only, pictures plus audio, and video. No significant differences were found between the four presentation formats. Zhu and

Grabowski (2006) found no significant differences in learning between drawings and animations where the subject was the human heart.

In some cases, a reduction was found in learning with multimedia compared to learning without multimedia (e.g., Lowe, 1999). Mayer, Hegarty, Mayer, and Campbell (2005) conducted four experiments on technical topics (e.g., lightning formation) where one group of learners had annotated illustrations and the other group had narrated animations. The annotated illustration group did as well as, if not better than, the narrated animation groups, which supported the *static media hypothesis* that static media are superior to dynamic media for learning. Tversky, Morrison, and Betrancourt (2002) argued against the dynamic media hypothesis and questioned those studies showing an advantage for dynamic over static visuals on the grounds that the visuals may not have been informationally equivalent or there may have been some confounding variables.

Other studies have found mixed results in comparing static and dynamic visuals, depending on learner characteristics and learning conditions. For example, Schnotz, Böckheler, and Grzondziel (1999) found empirically that animations aided learning in one type of learning, but that static pictures provided superior learning in most conditions tested. This can perhaps be explained by the increased *extraneous cognitive load* (Chandler & Sweller, 1991; Sweller, Ayres, & Kalyuga, 2011) caused by the animations compared to static pictures.

There is currently no consensus among media researchers that dynamic visuals such as animations enhance learning (Mayer & Moreno, 2002). This may be at least partially explained by the increased cognitive load on learners caused by dynamic visuals compared to static visuals within a given (usually short) time period (Hegarty, 2004; Lewalter, 2003). Viewers may look at a static visual for as long as they want, while non-interactive dynamic visuals are transitory and play automatically at a predefined rate (Höffler, Prechtl, & Nerdel, 2010). Here, *interactive* dynamic visual means more than the ability to merely start and stop the visual; it also includes the capability to move to a specific frame, change the playing speed (i.e., slower or faster), and zoom in or out. While viewers may replay a dynamic visual, they often do not take advantage of this capability, which means they may miss some details. One recommendation is to divide longer dynamic visuals into shorter segments (Ayres & Paas, 2007). An important advantage of interactive dynamic visuals such as virtual reality compared to non-interactive dynamic visuals such as animation is that *the learner controls* how the visual is displayed (L. J. Ausburn & Ausburn, 2008; Hegarty, 2004). Some view virtual reality as potentially more motivating to learners who don’t respond to other forms of media (Cobb & Fraser, 2005). Learner control addresses one possible explanation why non-interactive dynamic visuals may not be superior to static visuals. This explanation relates to the viewer’s previous knowledge of the subject, where novices often lack sufficient background to process complicated information from animations quickly enough (Lowe, 1999). A further possible explanation why non-interactive dynamic visuals may not be superior to static visuals is a reduction in the degree to which learners engage in processing activities (Lowe, 2003).

The studies cited here show there is no current consensus regarding what type of multimedia is best for learning. Then, *learner preferences* should be an important factor as higher interest may motivate the learner and increase learning, depending on the learner characteristics and the learning context (Renninger, Hidi, & Krapp, 1992). For example, Wright, Milroy, and Lickorish (1999) found that animations were more motivating than static diagrams to 60 female psychology students. However, there was no statistically significant difference in learning performance.

Mayer's Cognitive Theory of Multimedia Learning

Mayer (2009) offered 12 research-based principles for designing effective multimedia presentations which are based on his Cognitive Theory of Multimedia Learning:

1. **Coherence Principle**: exclude extraneous words, pictures, and sounds.
2. **Signaling Principle**: use cues to highlight the organization of the essential material.
3. **Redundancy Principle**: use graphics + narration, rather than graphics + narration + text that repeats the narration.
4. **Spatial Contiguity Principle**: corresponding words and pictures should be located close to each other.
5. **Temporal Contiguity Principle**: corresponding words and pictures should be presented simultaneously rather than successively.
6. **Segmenting Principle**: presentations should be divided into segments rather than in long continuous units.
7. **Pre-training Principle**: present the names and characteristics of the main concepts before the actual multimedia presentation.
8. **Modality Principle**: graphics + narration are better than graphics + text.
9. **Multimedia Principle**: text + pictures are better than text only.
10. **Personalization Principle**: text should be in conversational, rather than formal, style.
11. **Voice Principle**: narration should be in a friendly, standard accent, human voice rather than in a foreign accent or machine voice.
12. **Image Principle**: including a picture of the speaker on the screen does not necessarily improve learning.

Mayer's theory was derived from three other theories: (1) Baddeley's Working Memory Theory, (2) Paivio's Dual Coding Theory, and (3) Sweller's Cognitive Load Theory. According to *Baddeley's Working Memory Theory* (Baddeley, 1986, 2007; Baddeley & Hitch, 1974), humans have a limited capacity to process information in memory channels. This means multimedia designs should not overload a learner's memory channels or learning will be reduced. In *Paivio's Dual Coding Theory* (1986, 2007), text and graphics are encoded into two different memory channels: verbal and nonverbal. The theory suggests that multimedia designers should use both channels to reinforce concepts for the learner. However, while verbal and visual information can collaborate to enhance learning, they can also compete and reduce learning if not properly designed (Kirby, 1993). According to *Sweller's Cognitive Load Theory* (Chandler & Sweller, 1991; Sweller, 2005; Sweller, Ayres, & Kalyuga, 2011), instructional materials should not overload a learner's mental processing. For example, having a figure on one page and the text describing the figure on a different page increases the mental integration required by the learner which increases the cognitive load that could reduce learning. This theory suggests that multimedia designs should eliminate unnecessary processing for the learner. According to the *redundancy effect*, content that is unnecessarily redundant increases cognitive load and reduces learning (Sweller, 1999). For example, Kalyuga, Chandler and Sweller (2004) found that learning was reduced when narration simultaneously repeated on-screen text.

Multi-Image Presentations

Stimulus presentation methodology is where organisms are exposed to different types of stimuli to determine their reactions or performance. This methodology has been used in a wide range of fields such as psychology (e.g., Arciuli & Simpson, 2011), medicine (e.g., Carpenter, 2001), and child development (e.g., Jeffrey, 1961). It has also historically been used in multimedia research (Salomon & Clark, 1977). For example, Schmidt-Weigand, Kohnert and Glowalla (2010) used this methodology to study visual attention distribution in learning from text and pictures in multimedia learning using system-paced vs. self-paced instruction. The text for the instructional program on the subject of lightning was either written or spoken (narrated). The results showed that participants spent more time looking at the visualizations with spoken text, compared to written text (where they alternated between reading the text and looking at the visualizations). Another example is the study by Murray and Thomson (2011) who used the stimulus presentation methodology to study age-related differences on cognitive overload in an audio-visual word recall test.

Stimulus presentation in education has typically been done sequentially where participants view some type of presentation one page, slide, or screen at a time (e.g., Goolkasian & Foos, 2002). In this mode, groups of participants are typically assigned to different treatments and then the group performance means (usually some type of comprehension post-test) for each treatment are compared to each other to determine if one treatment is more effective than another. Another less common type of stimulus presentation research is when two different treatments are compared side-by-side. The latter stimulus presentation methodology was used in the present study of the multimedia preferences of working engineers.

One type of multimedia presentation is called *multi-image*, which is defined as "simultaneous projection of two or more pictures on one or adjacent screens for group viewing" (Kemp & Smellie, 1994, p. 392). The Association for Multi-Image (AMI) considered a multi-image program as consisting of an audio tape and three screens of slides or film (Burke, 1977-78). It may also include the use of audio synchronization. Various labels have been used to describe this instructional design method including multi-media, multi-screen, wide screen, multiple-image, multiple-screen, and non-linear projection (Owens & Coldevin, 1977). Multi-image presentations apparently date back to 1896 when Frenchman Claude Autant-Lara used multiple screens for a presentation on gold exploration (Bullough, 1981).

Perrin (1969) identified three major factors distinguishing multi-image from the conventional use of single-image media: simultaneous images, screen size, and information density. Simultaneous images are of particular interest in the present study. Ingli (1972) experimentally found that college classes assigned to multi-image instruction scored significantly higher than the control classes assigned to traditional single-image sequential instruction methods. Another important finding of the study was the multi-image classes completed the course content in 85% of the time compared to the traditional class, even though only about one-quarter of the course content was converted to multi-image. Therefore, multi-image may be more efficient for learning compared to single-image and is particularly effective for large audiences (Benedict & Crane, 1973). Multi-image presentations may also be more motivating for learners (Kemp, 1975).

Meyrowitz (1976) listed 11 relationships that are potentially present in multi-image presentations: redundancy, cross-modality redundancy, generic/specific, compare and contrast, relationship of interacting variables, parallel messages, analogical messages, temporal relationships, spatial relationships, generic concepts, and ideograms (combining images to form a concept). Dyer (1978) identified ten major strengths of multi-image presentations: comparison, contrast, multiple perspectives, sequence, juxtaposition, direct emphasis, sustained emphasis, motion effect, combining motion and still pictures, and the ability to create a panorama. The Meyrowitz relationship and the Dyer strength of particular interest in this study is *comparison*. The simultaneous presentation of multiple concepts results in more efficient learning (Beckman, 1977). Bullough (1981) similarly identified the comparison capability, but also noted that multi-image can increase information density and make learning more efficient if the presentation is properly designed.

Research on multi-image compared to single image presentations in learning contexts was very popular in the 1960s and 1970s (Moore, Burton & Myers, 1996). Multi-image research has traditionally focused on how the images were presented – simultaneously versus sequentially (Hutchinson, 1981). For example, Travers (1966) experimentally found simultaneous presentation to be consistently more effective than sequential. Much research has been done studying how multiple channels can be used to enhance learning (e.g., Hartman, 1961), where two different screens may be considered as two different channels (Goldstein, 1975). The research on whether multi-image presentations enhance learning compared to single-image presentations was generally considered inconclusive (Burke & Fradkin, 1978; Owens & Coldevin, 1977). Some researchers argued this was because multi-image had not been properly used, because too many senses had been engaged which overloaded the viewer's cognitive abilities to process the information (Owens & Coldevin, 1977).

Jonassen (1979) argued that simply having multiple simultaneous images does not necessarily lead to simultaneous mental processing and that there is no way to know exactly how individual viewers will perceive and interpret multiple images. He posited (p. 292), "The structuring of multi-image presentations should be designed by using established cognitive strategies based on existing theory. Multi-image is not a medium; it is a presentation technique that has potential for manipulating visual perception and, subsequently, cognition."

Clark (1971) examined multi-imagery's relationship to concept formation. In a meta-data study of research related to concepts, he found that using both positive and negative instances helped students to better understand concepts and that the bigger the difference between the positive and the negative instances the greater the learning. He also found that simultaneous display of four instances of a concept produced the best learning. In their instructional design guide for teaching concepts, Merrill and Tennyson (1977) supported Clark's findings and recommended one approach using direct comparisons with dual projectors. They recommended showing the best example of the concept first on the left projector, followed by showing a non-example of the concept on the right projector. If only a single projector is available, they suggested the left half of a slide could show the best example and then the right half of the slide could show a non-example.

Burke (1980) provided a less positive view of multi-imagery. He stated, “The successes of multi-imagery with traditional linear information are limited to young children, underachievers, and tactily-oriented haptic learners” (p. 159). In addition to the increased cost and complexity, Burke’s listed several shortcomings he believed may explain why multi-imagery was rarely used in educational contexts at that time.

Burke and Leps (1989) reviewed multi-image research over a 30-year period and claimed few studies were done and relatively little valid information had been produced. They wrote (p. 184), “very little beyond the level of common sense has been discovered which would serve theoreticians as a foundation for important statements on multi-image design and use.” Nearly all of the studies examined by Burke and Leps were limited to full-time students as the subject populations. Additionally, those studies did not follow Perrin’s (1969) recommendation for the multi-image presentations to enhance the basic message, but rather merely repeated it across multiple screens. However, some benefits were found in some studies for using multi-image compared to single image. These benefits included enhanced learning for under-achievers, haptics, and media novices, as well as improved retention, although some of the studies could not be replicated.

Multi-imagery was used in a completely different context and methodology by Berger (1973) who used a form of multi-images in psychotherapy which he termed *multi-image immediate impact video self-confrontation*. In this technique, the same videos are shown side by side where one screen is unadulterated and the other is deliberately distorted. The purpose is to help patients more freely associate about their past and present self-concepts and introjections, to help them gain greater insights into themselves. The technique was tested on 40 long-term patients where 70% spontaneously recalled memories of the experience in the weeks following the test.

Returning to a learning context, Fradkin (1974) studied the effectiveness of cognitive recall after viewing single-, two-, and four-image programs. The participants were 129 tenth-grade students in nine homeroom classes, with three classes assigned to each of the three treatments. The same set of 40 visuals was shown to each class and each visual was shown for the same amount of time. The difference was how many visuals were shown at one time. The total number of minutes to show the visuals was four, two, and one, for the single-, two-, and four-image projection tests, respectively. Participants were post-tested on recall immediately after viewing the images, after 24 hours, and a third time after one week. Recall was the best when the images were viewed singly and immediately after the test. Recall declined with more images being viewed simultaneously and with more time after viewing the images. However, this research design did not follow Perrin's (1969) recommendations for how to most effectively use multi-images to enhance learning as the multi-image presentations were essentially compressed versions of the single-image presentation.

Trohanis (1975) studied the presentation length of audible multi-imagery (AMI) presentations. AMI is a combination of multiple projection screens (three separate but contiguous screens in Trohanis' study) and with a corresponding audiotrack where a control system advances the slides. The primary variable of interest in that study was the program length, where essentially equivalent 10-, 20- and 30-minute presentations on high school psychology were used to study recall and retention. A total of 253 students in 10 classes from two high schools were sampled. The results showed that immediate and delayed (one week) retention were both highest for the 10-minute presentation. The shortest presentation was the most efficient program for learning.

Owens and Coldevin (1977) studied the effects of the time that images were shown in a dual-image presentation. The three treatments studied included a visual overlap of three seconds, six seconds, and fully overlapping. In the first two cases, two slides were shown simultaneously for either three or six seconds, after which one slide was removed and replaced with a blank slide.

The time the slides were shown simultaneously was controlled to be either three or six seconds. In the overlapping case, two slides were shown simultaneously but one of them was being dissolved out and replaced with another slide so there was a complete visual overlap. Any individual slide remained on the screen for between ten and twenty seconds. Taped narration accompanied the presentations. The results of the three treatments were also compared to a single-image presentation. The presentations were twenty minutes long and the topic was the nation of Zambia. The subjects were eighth graders from 10 classes from a suburban Montreal high school, where two classes were randomly assigned to the four experimental treatments (three multi-image and one single-image) and to a control group (post-test only). Scholastic ability as measured by mean scores on term examinations was used as a covariate. Significant differences were found for males who scored significantly higher than females and for subjects with high scholastic ability who scored significantly higher than subjects with low scholastic ability. All experimental treatment groups scored significantly higher than the control group which did not see any presentation. The only significant difference between treatments was the multi-image complete overlap group scored significantly higher than the three-second overlap group. This suggested that somewhere between a three second overlap and a complete overlap is recommended for optimal learning.

Jonassen (1979) experimentally studied the effects on learning of single- and multi-image presentations on plant biology for 362 seventh-grade students in life sciences classes in a suburban junior high school. Presentations on different plant classifications were shown on one, three, and four screens. In the single-screen presentation, 41 slides were linearly sequenced. In the three-screen presentation, additional examples and non-examples were included (a total of 115 different images) compared to the single screen presentation, following the recommendations of Clark (1971) and Merrill and Tennyson (1977). In the four-screen presentation, a total of 75 images were displayed including the original 41 slides plus 34 of those original slides repeated, again showing both examples and non-examples simultaneously. Participants were given tests to measure their conceptual style (analytic vs. relational), field articulation (analytic vs. global), and focal attention (scanners vs. focusers). They were also tested on their ability to classify plants after viewing the various types of presentations. The results showed that students' plant classification performance was better for the multi-screen than for the single screen presentation, although it was only statistically better for the four- vs. single-screen presentations. None of the learner styles was a significant predictor of plant classification performance.

Whitley and Moore (1979) studied the effects of presentation mode (single-image vs. multi-image) and student perceptual type (haptic vs. visual). Extreme haptics only use their eyes when they have to and use touch and kinesthesis otherwise, as compared to extreme visuals who depend on visual experiences (Lowenfeld, 1945). Whitley and Moore hypothesized that using multi-image presentations would aid haptics who have difficulty mentally retaining visual imagery. The subjects were 40 visual and 40 haptic students selected from a group of 200 English students from a community college in Virginia. Perceptual types were determined using Lowenfeld's Test of Subjective Impressions and Visual-Haptic Word Association Test. The presentations contained 20 groups of pictures, where each group contained three similar pictures from art books. In a post-test, subjects had to select the criterion photo in each group of pictures. The haptic and visual groups were each divided into two groups: single-image and three-image presentations. The results showed that visuals scored significantly higher than haptics regardless of how many images were used and that haptics scored significantly higher when viewing the simultaneous multi-image presentation compared to the sequential single-image presentation. There was no significant difference for visuals viewing the single- or multi-image presentations. This confirmed the results of Ausburn's (1975) earlier study of sequential versus simultaneous multiple imagery with visual and haptic learners.

Jurgemeyer (1980) noted that multi-image research studies produced conflicting results on the ability of multi-image presentations to enhance *learning*. He designed a study to see if multi-image has the capability of changing the *attitudes* of viewers. The topic for the presentations was instructional display boards (bulletin boards) which was traditionally relatively uninteresting for undergraduates taking an introductory audiovisual methods course. Forty-four students from the audiovisual class participated in the research. This study did not compare single-image vs. multi-image presentations as only a three-screen presentation was used. Both an attitudes and an applications test were given to the participants. The results showed that the multi-image format was not very successful for learning performance as only 28% of the students achieved the desired target of at least 90% correct on the applications test. This result was not compared against how students performed in previous classes which did not use the multi-image presentation. However, the multi-image format was successful in changing students' attitudes to be more favorable toward the content compared to their attitudes before the presentation. Again, this was not compared to students' attitudes in previous classes before and after studying that topic, so it is unclear how students' attitudes after the multi-image presentation compared to those after the traditional single-image presentation.

Leps (1980) hypothesized that learners with a more holistic or non-linear cognitive style would learn better with multi-image presentations and that learners with a more serial or linear cognitive style would learn better with single-image sequential presentations. The topic used for the study was photography. Cognitive style was determined using several instruments. The sample consisted of 190 undergraduate students who were randomly assigned to the experimental groups. Pre-test scores were a covariate in the study. The results showed no statistically significant difference in post-test scores so the research hypothesis was not supported. The single- and multi-image presentations were not identical in length or content which could have been confounding variables in the study.

More recently, Kuo, Chang, Hsu, and Yu (2009) experimentally compared single-screen and dual-screen presentations where the topic was programming language instruction. The participants were undergraduate students where 23 were randomly assigned to the single-screen and 19 to the dual-screen presentations. The content was identical in both formats; however the material was presented sequentially in the single-screen format and simultaneously in the dual-screen format. The results showed that students had better perception and felt the learning materials were clearer and easier using the dual-screen/simultaneous compared to the single-screen/sequential presentation.

Wiseman and Gordon (1978, p. 3) wrote as a summary of the mixed findings of multi-image research, “multi-image provides a further flexible alternative along with other traditional means of large group instruction.” This body of early research on the effects of multi-images on learning was clearly inconclusive. Salomon and Clark (1977) argued that research on the effectiveness of multimedia in general was inconclusive because the only factor that varied in the gross media comparison research studies was the delivery mechanism because the content was essentially the same. They called for research in more realistic contexts (higher external validity) to study the interaction between the learner and the medium to find the best way to use that medium and under what conditions. No research was found by this researcher on the use of multi-image presentations to enhance learning for adults (i.e., beyond college students), which is the subject of the research presented here.

Stimulus presentation methodology using multi-image presentations was of particular importance in the present research study because it allowed participants to directly compare two different types of media. In the conventional single-image sequential presentation format, the subject must hold an image in memory in order to compare it against the image on the screen, unless smaller images are displayed simultaneously side-by-side. According to Lowenfeld (1945), keeping images in memory is particularly challenging for individuals with a more haptic perceptual style. Perrin (1969, p. 376) wrote, “Simultaneous images reduce the task of memory and enable the viewer to make immediate comparisons.” As demonstrated by Whitley and Moore (1979), multi-image display enhances perception particularly for haptics. Based on these assertions, in the present study, a dual-image simultaneous presentation was used and is argued to have produced a generally better environment for comparison of multimedia types than a single-image sequential presentation.

Learner Differences

The *principle of individual differences* states that instructional design may affect learners differently, depending on their prior knowledge and their cognitive spatial abilities (Horz & Schnotz, 2010). Simonson et al. (2012) stressed the importance of knowing the learners when designing distance course materials. Learner characteristics are an important consideration when selecting the proper media during instructional design (Clark & Lyons, 2011; Gagné, Briggs, & Wager, 1992; Silber, 2010). Instructional design should not center around the media, but rather around the learner (Jonassen, Campbell, & Davidson, 1994). Incorporating learner characteristics in online multimedia engineering education is important (Al Mashakbh, Din, & Halim, 2013). Seaman and Fellenz (1989, p. 17) wrote, “Those who develop or facilitate learning activities for adults should definitely pay attention to the personal preferences of the students . . . the teacher must select strategies that enable adults to achieve preferences for learning.” *Supplantation* refers to tailoring instructional design by using instructional modes preferred by the learner (Ausburn & Ausburn, 1978a,b; Ausburn & Ausburn, 2003; Salomon, 1970). This has also been referred to as the *meshing hypothesis* where instructional design is matched to a learner’s preferred presentation style (Paschler, McDaniel, Rohrer, & Bjork, 2009). More specifically, *conciliatory supplantation* capitalizes on the strengths and preferences of learners. This obviously means those strengths and preferences must be known by the instructional designer. As an example of the effect of learner characteristics, Ausburn and co-workers (Ausburn, 2012; Ausburn, Martens, Washington, Steele,

& Washburn, 2009) studied a desktop virtual reality environment and found some significant differences as a function of gender.

Prior Knowledge

Prior knowledge is sometimes referred to as expertise. Park and Hannafin (1993, p. 67) wrote, “Related prior knowledge is the single most powerful influence in mediating subsequent learning.” In a review paper, Kalyuga (2007) came to the same conclusion. The assumption in most learning contexts is that the learners are novices, although this is not always the case. There are also different levels of prior knowledge including the specific domain of interest (e.g., calculus) and the general subject domain (e.g., mathematics). The amount of prior learner knowledge greatly affects cognitive load. What may be a high cognitive load for a novice may be a minimal cognitive load for an expert.

Mayer (2005a) categorized prior knowledge of the learner as one of the five forms of representation in his Cognitive Theory of Multimedia Learning. Prior knowledge is stored in long-term memory and can be recalled by the learner to be integrated with new knowledge when processing multimedia. According to Clark and Feldon (2005, p. 105), “the assessment of prior knowledge for the customization of multimedia instruction offers great promise.”

Learners are sometimes grouped in categories ranging from novices to experts based on their prior knowledge of a particular topic. The effectiveness of visual design in learning contexts is related to a learner’s prior knowledge of the subject (ChanLin, 1999). Some example research studies will illustrate this. Joseph and Dwyer (1984) found no significant difference in learning using different types of multimedia for low-prior-knowledge learners. However, there was an effect for high-prior-knowledge learners where a photograph was significantly more effective than text only. Lee, Gillan, and Harrison (1996) found different types of multimedia had different effects on learners with different levels of prior knowledge. Ollerenshaw, Aidman, and Kidd

(1997) showed that adding static graphics to text benefitted high-knowledge learners, but had essentially no effect on low-knowledge learners. Other studies have found the opposite where low- knowledge learners benefitted more from well-designed multimedia than high-knowledge learners (e.g., ChanLin, 1999, 2001; Grimley, 2007). For example, ChanLin (2001) found that 8^{th} and 9^{th} graders with low prior knowledge benefitted more from text plus graphics, compared to pure text or to an animation, while there were no significant differences in performance between the three media types for high-prior-knowledge learners.

Effective multimedia learning materials should link new information to the existing prior knowledge to facilitate knowledge-building in the learner (Ahola-Sidaway & McKinnon, 1999). Kozma and Russell (1997) experimentally demonstrated that experts are competent with a wider range of representations compared to novices. Kozma (2003) experimentally showed that experts also more easily make linkages between representations than novices. Animations need to be designed for the knowledge level of the learners, where learning can be reduced if animations are too complicated for novice learners (Lowe, 2003). These studies are consistent with Sweller's (2005) cognitive load theory where novices' memories are much more easily overloaded compared to experts, which reduces learning effectiveness.

An important consideration then for instructional designers is that learners with little prior knowledge in a subject area can be more easily cognitively overloaded compared to experts (Cook, 2006). According to the *expertise reversal effect* (Sweller, Ayres, & Kalyuga, 2011), instructional methods that are effective with less experienced learners may be ineffective, or even detrimental, with more experienced learners and vice versa. This effect was demonstrated experimentally by Kalyuga (2008) who found that more knowledgeable learners benefitted more from animations and less knowledgeable learners benefitted more from static graphics, and vice versa. Mayer and Gallini (1990) partially validated this effect where they found low-experience learners benefitted from one type of treatment and not another, but there was no difference in learning between treatments for the high-experience learners.

Learning Strategy Preferences

To meet the needs of individual learners, there has been considerable research interest in how students approach learning tasks (Ausburn & Brown, 2006). One method of assessing this learner variable is referred to as *learning strategy preference*, which is an important characteristic that varies among learners. Fellenz and Conti (1989) noted that learning strategies are techniques or skills that individuals choose to use while learning. Strategies tend to be selected for a specific task and therefore differ from styles which tend to be stable traits.

Three distinct learning strategy groups have been identified by Conti (2009): Navigators, Problem Solvers, and Engagers. As described by Conti, *Navigators* plan their learning and focus on completing the necessary activities to achieve their goals. Order and structure are important to Navigators, who tend to be logical, objective, and perfectionists. They want clear objectives and expectations at the beginning of a course and in advance of activities, such as in an explicit and detailed syllabus. *Problem Solvers* are critical thinkers who like to explore multiple alternatives. For them, the process is important so they need flexibility in completing learning activities. They may have difficulties making decisions because they have to make a choice among multiple alternatives and because the exploration process which they enjoy must come to an end. This may cause them to appear to procrastinate in making decisions because they do not want the process to end. *Engagers* are more affective learners who enjoy learning they perceive to be fun or personally beneficial. They are interested in building relationships with both teachers and fellow students during learning, which means they typically enjoy group activities. The emotional aspect of learning is important to Engagers.

Conti (2009) compiled data from numerous studies and found that on average there is approximately an even split among the three types of learning strategy preferences in the general population. Various studies have found that certain learning strategy preferences may be more prevalent for a particular group of people. For example, Ghost Bear and Conti (2002) found in a sample of eBay users that most were Problem Solvers. Ausburn and Brown (2006) studied career and technical education students and found that most were Engagers. Baukal, Ausburn, Mattson, and Price (2013) found that in a sample of engineering students, most were Problem Solvers. Table 1 shows a comparison of these data.

Table 1

Learning strategy preference profiles as measured by ATLAS for various research studies.

Study	Subjects	*N*	Navigators	Problem Solvers	Engagers
Birzer & Nolan, 2002	Police officers	80	23.8%	50.0%	26.3%
Ausburn & Brown, 2006	Career & technical education students	617	24.3%	30.3%	45.4%
Conti, 2009	General population	3070	36.5%	31.7%	31.8%
Baukal et al., 2013	Engineering students	195	33.3%	39.5%	27.2%

Different professions may have different learning strategy preference profiles. For example, Birzer and Nolan (2002) found (see Table 1) that law enforcement had a distinctive profile compared to the general population in a comparison of known population norms to the preferred learning strategies of urban police in a Midwestern city. They found there were some differences between those working in community policing environments and those who were not. Police involved in community policing tended to be Problem Solvers. To date this researcher was unable to find any studies to determine the learning strategy preferences of engineers, the occupational group of interest in this study.

Only one study was found that related learning strategy preferences to multimedia. Jones (2002) studied learning performance as a function of learning strategy preference and instructional treatment (text or video presentation) for university students taking an educational technology course. No statistically significant results were found for either of the main effects of learning strategy preference or instructional treatment or for the interaction of these variables.

Knowledge of learning strategy preferences can be used by instructors to select appropriate instructional design methods, learning activities, and course content (Conti & Kolody, 2004). Learning strategies as defined and measured by the ATLAS instrument represent the *strategic aspect of adult learning preferences*. This variable was included in this study to examine possible relationships between strategic learning choices and multimedia preferences.

Verbal-Visual Cognitive Style

A major dimension of cognitive style is the verbalizer-visualizer dimension (Paivio, 1971; Riding, 2001). Unfortunately, there is no consensus on terminology for this dimension as it has been called a cognitive style, a learning style, and a learning preference (Plass, Chun, Mayer, & Leutner, 1998). According to Jonassen and Grabowski (1993), "Visualizers tend to think more concretely, use imagery, and personalize information. While learning they prefer graphs, diagrams, or pictures added to text-based material. Verbalizers prefer to process information from words, either by reading or listening, rather than through images" (p. 191). Learners who have no strong preference for either verbal or visual processing are referred to as *flexible stylists*, also called *bimodal* or *mixed processors* (Ong & Milech, 2004). More visual learners may approach learning tasks with visual learning strategies, while more verbal learners may use more verbal strategies (Kirby, Moore, & Schofield, 1988). When given a choice, verbalizers tend to select more verbal content and visualizers tend to select more visual content (Riding & Watts, 1997). Verbal-visual cognitive style is a particularly important dimension in the design of multimedia learning environments (Mayer & Massa, 2003). There are some, however, who argue there is not adequate evidence yet to support using cognitive styles assessments in educational practice (e.g., Paschler, McDaniel, Rohrer, & Bjork, 2009).

The *verbalizer-visualizer hypothesis*, sometimes called the *matching hypothesis*, is that verbalizers learn more effectively with verbal materials and visualizers with more visual material (Hayes & Allinson, 1996; Kollöffel, 2012; Plass, 2004; Riding & Watts, 1997). “The claim is that when students are matched with their preferred instructional mode, achievement and satisfaction with learning will be enhanced” (Hudak, 1985, p. 402). Plass, Chun, Mayer, and Leutner (1998) and Thomas and McKay (2010) experimentally found strong support for this hypothesis. Höffler and Schwartz (2011) experimentally found that visualizers learned better with animations than verbalizers, which was expected because animation is a highly visual technology.

However, other studies did not validate this hypothesis. Alesandrini, Langstaff, and Wittrock (1984), Chen and Sun (2012), Kollöffel (2012), Massa and Mayer (2006), and Moreno and Plass (2006) all showed experimentally that learning was not necessarily best when using one’s preferred cognitive style. For example, Alesandrini et al. (1984) did not find any correlation between cognitive style and learner performance, even though they did find more favorable learner attitudes toward learning when the instructional strategy matched the learner’s preferred cognitive style. Mendelson and Thorson (2004) found mixed results where verbalizers were better at text comprehension from newspaper articles than visualizers, but that the addition of a photo actually helped the verbalizers and not the visualizers. Chen and Sun (2012) found that learning performance with video-based material was more effective than with text-based material for both verbalizers and visualizers. Liu, Kinshuk, Lin, and Wang (2012) found no significant difference in learning performance for verbalizers and visualizers in a highly visual computer-assisted learning simulation. The mixed and inconclusive findings regarding the effect of matching verbalizer-visualizer cognitive style with learning materials to enhance learning performance indicate this is an area requiring further research.

Many instruments have been developed to measure this cognitive style variable. Richardson (1977) developed a 15-item questionnaire called VVQ (verbal and visual questions). His research showed 15% to 25% of people tested fell into what he called either habitual verbalizers or habitual visualizers, with the balance in between. He recommended using 15% verbalizers and 15% visualizers with the balance in between for research purposes. While the VVQ has been used in many studies, its validity and the validity of a related test, the Cognitive Styles Analysis, have been questioned (Antonietti & Giorgetti, 1998; Childers, Houston, & Heckler, 1985; Massa & Mayer, 2005). Moreno and Plass (2006) speculated that the VVQ might be more a measure of verbal-visual preference, rather than of cognitive style. Felder and Silverman (1988) wrote a frequently-cited paper on learning and teaching styles in engineering education. One of the five dimensions they discussed included visual-auditory. An instrument was then developed (Soloman & Felder, 1991) that is a self-scoring 44-item questionnaire called the Index of Learning Styles (ILS). One dimension measured by the ILS is the verbal-visual. Originally, verbal was called auditory but was later changed to reflect that written text is visual but does not accurately reflect the visual dimension which refers to pictures, drawings, videos, etc. The instrument was determined to be reliable and valid based on an analysis of multiple studies in which it was used (Felder & Spurlin, 2005). Montgomery (1995) used the ILS instrument to sample the learning styles of 143 students in an introductory sophomore-level chemical engineering class. She found that 69% were visual and 30% were verbal (1% were reported as None). Multimedia software was developed for the course, in part because multimedia software favors visual learners which were the overwhelming majority of the engineering students studied. Rosati (1999) used the ILS to sample a large group (N = 858) of engineering students at the University of Western Ontario and found that 80% were visual (89% of males were visual, 69% of females). Kirkham, Farkas, and Lidstrom (2006) found that 86% of the University of Washington engineering students taking a particular class were visual as determined using the ILS. Plass, Chun, Mayer, and Leutner (1998) experimentally studied verbal and visual learning preferences in a multimedia learning environment in the form of annotations of words in a German language story for English-speaking college students taking a German class. They found that visualizers had better comprehension when they used the visual annotations (either a picture or a video) and the verbalizers did better when they used the verbal (English text) annotations. Plass and Homer (2002) used a visual observation method developed by Leutner and Plass (1998) called the Visualizer/Verbalizer Behavior Observation Scale (VV-BOS) and classified those scoring in the upper, middle, and lower third of the scale as verbalizers, controls, and visualizers, respectively.

The ILS instrument measures four dimensions of cognitive style, only one of which is of interest in this study. It also consists of 44 questions, which would have significantly lengthened the survey for the present research. That would likely have reduced the response rate and possibly biased the results due to participant fatigue. Therefore, a simpler instrument was sought. The verbalizer-visualizer preference as measured by the Verbal-Visual Learning Style Rating (VVLSR) was developed by Mayer and Massa (2003). It consists of a single question and represents the *perceptual cognitive aspect of adult learning styles*. This instrument compared favorably with, for example, the Verbalizer-Visualizer Questionnaire and the Cognitive Styles Analysis instruments discussed above, although it was not compared against the ILS. Therefore, the VVLSR was selected for the present study to measure the verbalizer-visualizer cognitive style. This variable was included in this study to examine possible relationships between perceptual/cognitive learning choices and media preferences. It was also included in the study to compare with verbal-visual media preferences.

CHAPTER III

METHODOLOGY

General Research Design

This study used a quantitative descriptive design based on survey methodology (Fowler, 2014), where instruments such as questionnaires are used to collect information such as attitudes, beliefs, opinions, or practices from one or more groups of subjects (Ary, Jacobs, Razavieh, & Sorensen, 2006; Creswell, 2012; Gay, Mills, & Airasian, 2009). More specifically, this study was a cross-sectional survey where data were collected at a single point in time. Surveys are used by researchers to determine the characteristics of different groups or to measure attitudes and opinions toward an issue. Survey research describes distributions of variables in groups, rather than making causal inferences. This study investigated a portion of the total population of John Zink engineers, a method referred to as a sample survey. The survey technique used here was directly-administered questionnaires, which were given to a group of participants assembled for a particular purpose at a certain place.

Variables and Design Controls

The general occupational discipline for all subjects in the study was engineering. The subject matter for the study was a particular piece of technology called the COOLstar® ARIA burner. Informational equivalence (Mayer, Hegarty, Mayer, & Campbell, 2005) was maintained as much as possible among presentation designs. For example, the labels and descriptive text used with the static visuals were identical to those used with the dynamic visuals. A single narrator, the researcher, was used for the narration, as changes in narration voice tone can add additional information compared to text only (Mayer et al., 2005).

This study was not a true experimental research design with traditional independent and dependent variables. Therefore, it could be argued there were no dependent variables. However, research questions 6 through 11 investigated relationships among variables. Those relationships are the basis for determining the independent and dependent variables here.

Independent Variables

The demographics of the participants were considered here to be the independent variables. These were compared against the learner characteristics of learning strategy preference, verbal-visual cognitive style, and multimedia preferences to determine possible relationships. The demographic of gender had two levels: female or male. Three demographics had a year range: age, total years of engineering work experience, and total years of engineering work experience at John Zink. The highest attained engineering degree (Bachelors, Masters, and Ph.D.) and engineering specialty (mechanical, chemical, etc.) for the highest engineering degree were independent variables for each subject. Management level in the company was an independent variable and had three levels: individual contributor (no management responsibilities), middle management (team leader, supervisor, director), and senior management (vice president, chief financial officer, or president). Some subjects had a professional engineering license and some did not. The subjects had different prior knowledge of the subject matter.

Dependent Variables

The dependent variables for the study were the learner characteristics of the participating engineers. The preferred learning strategy of subjects was a key dependent variable and had three levels: Engager, Navigator, and Problem Solver. A second key dependent variable was the subjects' verbal-visual cognitive style. The principle dependent variables of interest were the preferences of the participating engineers for the various multimedia designs presented to them.

Learning performance was not a dependent variable in this study because of both the type of training and the research design. Because the course type of interest concerned continuing education, students taking those courses are expected to achieve at least 80% on a posttest to show satisfactory completion. The posttest questions are designed to test basic factual information, but not deeper level comprehension. Therefore, it would have been difficult to determine significant differences in learning between the various types of multimedia unless more challenging questions were developed than are actually used in the courses. It was originally estimated that approximately 80 engineers from JZHC would participate in the study. Even if the performance measurement challenge discussed above did not exist, there would not have been enough participants to measure statistically significant differences in learning performance for all the various types of multimedia that were considered in the study. Learning performance could have been experimentally measured for each type of multimedia if there were enough participants to form separate groups to view each type. Each group could only have seen one multimedia type because if they saw other designs they might have had too much prior knowledge which would have biased the results. Gay et al. (2009) recommended a minimum of 30 participants in each group being compared. In the present study, eight multimedia types were compared. This would have meant that a minimum of 240 participants would have been needed. In the present study, there were too many multimedia designs and not enough participants to make the groups large enough to provide statistical power to yield statistically significant results for learning performance.

As an exploratory study, this research had the purpose of describing learner and multimedia *preferences and characteristics*, not of experimentally determining the effectiveness of multimedia formats on learning performance.

Population and Sample

A research population is defined as “all members of any well-defined class of people, events, or objects” (Ary et al., 2006, p. 167). A sample is defined as “a group of individuals, items, or events that represent the characteristics of the larger group from which the sample is drawn” (Gay et al., 2009, p. 124). Convenience sampling is “the process of including whoever happens to be available at the time” (Gay et al., 2009, p. 134). In this study, convenience sampling was used because any engineers from the JZHC in Tulsa, Oklahoma willing to participate were included in the study.

The general population of interest for this research was working engineers. The specific target population was engineers working at JZHC in Tulsa, Oklahoma, which at the time of the survey was 174 as identified by the Human Resources (HR) department of the company. This included people who either had an engineering degree or had some type of title with “Engineer” in it. Some example titles included Process Engineer, Applications Engineer, CFD (Computational Fluid Dynamics) Engineer, Controls Engineer, Design Engineer, Development Engineer, Engineering Manager, and Project Engineer. For most of these titles, there were multiple levels such as Controls Engineer I, Controls Engineer II, and Sr. Controls Engineer. All

JZHC engineers were invited to participate in the study and about two-thirds did participate voluntarily which made up the sample for this study as reported below.

The gender distribution for the 174 population engineers included 152 males and 22 females. The management distribution included 133 individual contributors, 31 middle managers (supervised at least 1 person), and 10 senior managers (Vice Presidents, Chief Financial Officer, and President). The only other data provided by HR was the group each employee worked in and their supervisor. Other information collected in the survey such as age, total years of work experience, and years worked at JZC was not provided by HR.

In the Phase 1 and Phase 2 surveys for this study, described below, there were 86 (49.4% participation) and 110 (63.2% participation) participants, respectively. Details of the demographics of those participants are provided in Chapter IV. There were a total of 118 participants (67.8%) who took at least one of the two surveys. Only eight of those who took the Phase 1 survey did not take the Phase 2 survey.

Instrumentation and Instrument Design Procedures

Design of Two Multimedia Preference Surveys

Two surveys were developed by the researcher for this study: one for Phase 1 (see Appendix A) and one for Phase 2 (see Appendix B). The Phase 1 survey had two versions (A and B) which are shown in Table 2. The Phase 2 survey had two versions (C and D) which are shown in Table 3. The only difference between the versions in each phase was the relative screen positions of the multimedia types, which were reversed. For example, the drawing was shown on the left screen in version A of the Phase 1 survey and on the right screen in version B. This was done for two reasons. One was to minimize the effects of diffusion of information between participants, in case earlier participants told later participants which screens they preferred. Another reason was to minimize the potential bias based on where participants sat in the room.

For example, if there was any overall bias toward picking multimedia types on a certain side of the room, switching sides in different versions was designed to minimize those effects.

Table 2

Phase 1 survey versions.

Multimedia Pair	Survey A		Survey B	
	Left Slide	Right Slide	Left Slide	Right Slide
1	labels	description	description	labels
2	drawing	photo	photo	drawing
3	video	animation	animation	video
4	simulated VR	real VR	real VR	simulated VR

Table 3

Phase 2 survey versions.

Multimedia Pair	Survey C		Survey D	
	Left Slide	Right Slide	Left Slide	Right Slide
5	description	drawing	drawing	description
6	animation	simulated VR	simulated VR	animation
7	drawing	animation	animation	drawing
8	simulated VR	description	description	simulated VR
9	description	animation	animation	description
10	drawing	simulated VR	simulated VR	drawing

The Phase 1 pairs were generally arranged from less concrete (verbal was the least concrete) to more concrete (interactive dynamic graphic was the most concrete). No attempt was made to randomize the order of the pairs as these were strictly within-category comparisons.

Within a given category of multimedia, one in the pair was considered less concrete and one more concrete (see Table 4). For example, in the static image category, a drawing is considered less concrete than a photograph. On a given screen (left or right), the multimedia types were alternated between less concrete and more concrete, to minimize any bias that might have occurred by having less concrete multimedia always on one side and more concrete always on the other side.

Table 4

Phase 1 multimedia pairs (within-type comparisons).

Pair #	Multimedia Category	Less Concrete Slide	More Concrete Slide
1	Verbal	Labels + description	Labels + narration
2	Static Graphic	Drawing	Photograph
3	Non-Interactive Dynamic Graphic	Animation	Video
4	Interactive Dynamic Graphic	Simulated VR	Real VR

The multimedia pairs in Phase 2 were selected only after the highest preferences from Phase 1 were determined. Six pairs were used in Phase 2, which were all the possible combinations of four different items taken two at a time where the order doesn't matter. In this phase where different categories of multimedia were being compared, the order of the pairs and which type appeared on the left slide and which appeared on the right slide were randomized. This was done to minimize any biases that might have occurred if participants had biases toward the left or the right side or towards the order of presentation, such as preferring what they saw first or last.

Four Instruments Included in Survey Set Administered to Participants

The surveys administered to the subjects consisted of a combination of four separate instruments: demographic questionnaire, ATLAS, Verbal-Visual Learning Style Rating, and multimedia preference (described above).

Demographic questionnaire.

The participant demographic questionnaire was developed by the researcher (see the second page and the top of the third page of the surveys in Appendices A and B) and was used to collect descriptive information. This included gender, age range, total engineering work experience range, total engineering work experience at John Zink range, management level at John Zink, highest engineering degree, specialty for the highest engineering degree, and whether or not the participant was a licensed Professional Engineer. There were no previous studies found examining the demographics of working engineers regarding their learner and multimedia preferences to use as a basis for designing the demographics questionnaire used here. The demographics for this study were selected as the most likely to have a possible correlation with those preferences. They were also selected because it was believed they would be most honestly answered. For example, it was not believed participants would have provided accurate salary data. Other potentially personal data such as race and ethnicity were excluded as they would not likely have been approved by the company's human resources department. Ranges were used for age and work experience as it was believed those would be more honestly answered than asking for actual values and because the human resources department would not likely have approved actual values since that could have made it possible to identify individual employees.

The participants were also asked to specify their prior knowledge of the subject technology, the COOLstar ARIA burner, using the following five-point scale: *Extremely knowledgeable* (e.g., invented, design, test, or sell this burner), *Very Knowledgeable* (e.g., invented, design, test, or sell <u>original</u> version of the COOLstar burner), *Knowledgeable* (e.g., invented, design, test, or sell other types of process burners but not the COOLstar), *Somewhat* knowledgeable (e.g., not that familiar with process burners but familiar with other types of burners), and *Little or no knowledge about this technology* (e.g., may have heard or seen this technology but that's about it). No numbers were shown on the scale which might have biased the results if participants thought higher or lower numbers were preferred

ATLAS test of adult learning strategy preferences.

The second instrument incorporated into the surveys was a simplified version of the ATLAS instrument (Conti, 2009), which is shown in Appendix C. This was used to determine each subject's learning strategy preference. In the original version of ATLAS, there are subtypes which were not of interest in this study and were eliminated to simplify and shorten the survey. Eliminating the subtypes did not affect the validity of the instrument as most of the studies using ATLAS also only reported the overall types and not the subtypes. Conti (2009) who developed ATLAS also only reported results for the major types and not the subtypes. After determining their learning strategy preference, participants were then asked how accurately they believed the description of that preference given on page 2 of ATLAS described them as a learner. The following seven-point scale was used: *Strongly agree*, *Moderately agree*, *Slightly agree*, *Neither agree nor disagree*, *Slightly agree*, *moderately agree*, and *Strongly disagree*. Again, no numbers were used which might have biased participants' selections.

Verbal-Visual Learning Style Rating.

The third instrument used in the surveys was the Verbal-Visual Learning Style Rating (Mayer & Massa, 2003). This was used to determine each participant's verbal-visual preference. It consisted of a single question (see the bottom of page 3 in each of the questionnaires in Appendices A and B). Participants were asked to rate their verbal-visual preference using the following seven-point scale: *Strongly more verbal than visual*, *Moderately more verbal than visual*, *Slightly more verbal than visual*, *Equally verbal and visual*, *Slightly more visual than verbal*, *Moderately more visual than verbal*, and *Strongly more visual than verbal*. No numbers were used to identify the selections.

Multimedia preferences.

The fourth instrument was developed by the researcher to determine the participants' multimedia preferences as described previously. The subjects' multimedia design preferences among eight different multimedia types were measured in two phases. The reason for two phases was that if all eight types were compared to each other in pairs, where the order did not matter, this would have been 28 different combinations. That would have been too many to compare as it would likely have fatigued the participants and biased the results. Instead, the comparisons were broken into two phases to dramatically reduce the number of pairwise comparisons to a total of 10 (four in Phase 1 and six in Phase 2) spread over two sessions. Phase 1 compared within the four categories of multimedia considered in this study (text, static graphics, non-interactive dynamic graphics, and interactive dynamic graphics). Phase 2 compared between the four categories.

Three different methods were used to compare the multimedia types. The first was a relative preference between the multimedia type shown on the left screen compared to that shown on the right screen. This is known as *stimulus presentation methodology* commonly used in multi-image research as previously discussed in Chapter II. A seven-point scale was used: *Strongly prefer left slide, Moderately prefer left slide, Slightly prefer left slide, No preference, Slightly prefer right slide, Moderately prefer right slide, Strongly prefer right slide*. The second method of comparison was rating each type on a scale of 0 ("hate it") to 100 ("love it"). The third method of comparison was ranking where 1 indicated "like most" and 2 indicated "like least."

One reason for using three methods was to triangulate the results, in case a participant made a mistake during a comparison, which actually did happen although not very frequently. In the preference method, no numbers were used. In the rating method, a higher number indicated a higher preference, while in the ranking method a lower number indicated a higher preference. Another reason was to try to measure the strength of the difference between two multimedia types in a comparison. For example, rating one type with a zero and the other type in a comparison with a 100 would show the participant strongly preferred one over the other. A third reason for multiple methods was to force a preference using the ranking, even if a participant selected no preference and rated two multimedia types equally.

The eight multimedia types were kept as informationally equivalent as possible, because having different content can confound the results (Gunter, 2010). Essentially, the same information was presented in all eight types. The same subject matter was used and nine different component parts were displayed in each multimedia type. This included displaying each part for approximately seven seconds, so the total amount of time that each type was shown using PowerPoint to the participants was approximately 63 seconds. The same component description was used in all multimedia types.

Instructional design quality has been identified as a confounding variable in many past studies comparing various types of multimedia (Gunter, 2010). Here it was made as uniform as possible. The same font type (Arial), font size (22), and font color (light green = red 204, green 255, and blue 153) were used in all eight multimedia types. Arial was chosen because it is a sans serif font which is more readable in computer-based presentations (Lohr, 2008). The maximum font size, which is more important than font color in terms of legibility (Pett & Wilson, 1996), was used to display all of the information on one screen with suitable blank space around the edges of each slide for visual appeal (Lohr, 2008). A light color font was chosen to maximize contrast against the black background. Kalyuga, Chandler, and Sweller (1999) experimentally showed that color coding text helped negate the split-attention effect when graphics and text are shown simultaneously in multimedia instruction. Therefore, color was used here as a visual cue for the viewer. A green font was chosen because green has been found to be a pleasant color associated with “good” in computer displays (Hall & Hanna, 2004). All multimedia types were displayed on a black background. While a white background with dark text is generally preferred for maximum legibility (Greco, Stucchi, Zavagno, & Marino, 2008), in this case the subject matter technology (a burner) was mostly white and light gray in color, so maximum contrast for best visibility was achieved with a black background (see Figure 8).

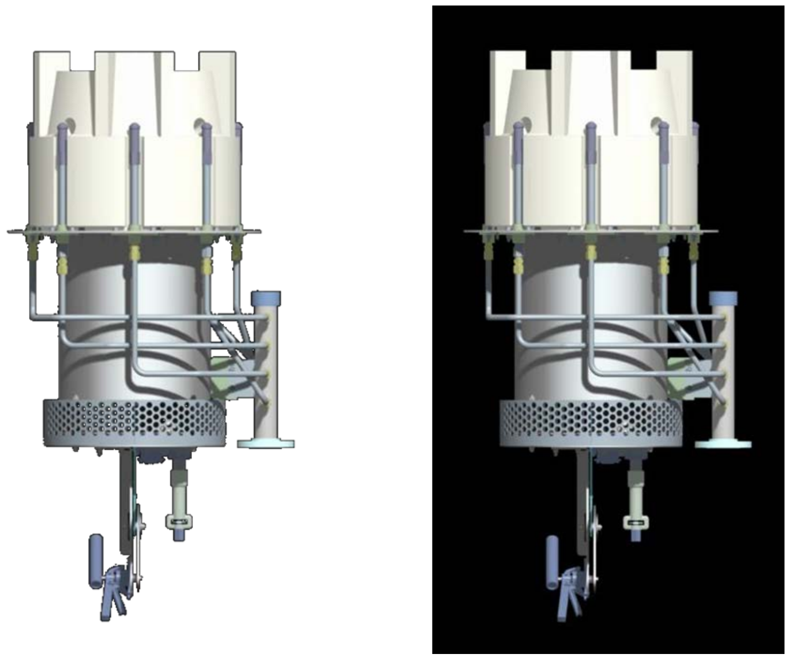


Figure 8. Comparison of burner displayed with a white (left) and a black (right) background.

Recommended instructional design principles for effective multimedia presentations (Faraday & Sutcliffe, 1997) were followed. Labels were revealed gradually to direct the learner’s attention, elements were revealed in a sequence rather than simultaneously, reading time was allowed after cueing a label, and symbols (arrows in this case) were used to direct attention to specific objects (Schnotz & Lowe, 2008). Blake (1977) found that learning was enhanced when arrows were used to direct learners' attention in instructional photographs (static graphic), compared to not using arrows.

Five components were shown on the left side of the image and the remaining four on the right, except for the label + description type where all nine components were stacked vertically with the labels on the left. The components were shown working from the top to the bottom and alternating between the left and the right, except for the label + description type where they were shown starting at the top and descended downwardly. The order and positioning of the components displayed was designed so that no descriptions referred to another component unless it had already been displayed. For example, the descriptions for both the *manifold* and the *riser* refer to the *tip* which had already been displayed prior to those components being displayed. Component descriptions were very succinct so all the information could be displayed on a single screen without excluding any needed information.

No identifying information was included on the slides that specified what multimedia type was being displayed. This was done to minimize any bias that might have occurred based on the name of the type, in case participants had preconceived beliefs that one type was superior to another type before even seeing the slides.

For the label + description multimedia type (see Figure 9), it took a half second using PowerPoint's fade animation feature to display the label simultaneously with the description. This remained on the screen for another six seconds in the green font. After that, the font changed from green to dark gray (see Figure 10) using the font color change option which took a half second. Dark gray allowed the participant to see previous labels, while the green highlighted the component being considered at the moment. Seeing previous labels allowed the participant to see previous components that may have been included in the current component's description. The total cycle for each component was seven seconds.

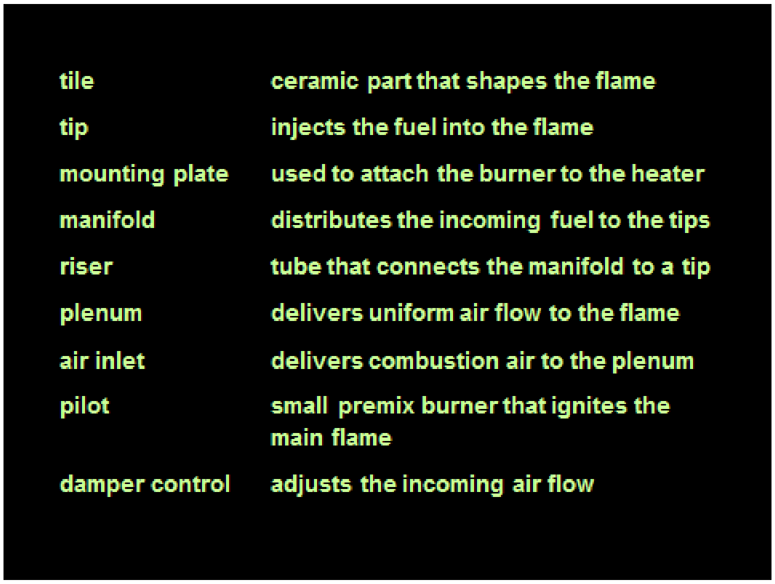


Figure 9. Label + description multimedia type with all components displayed.

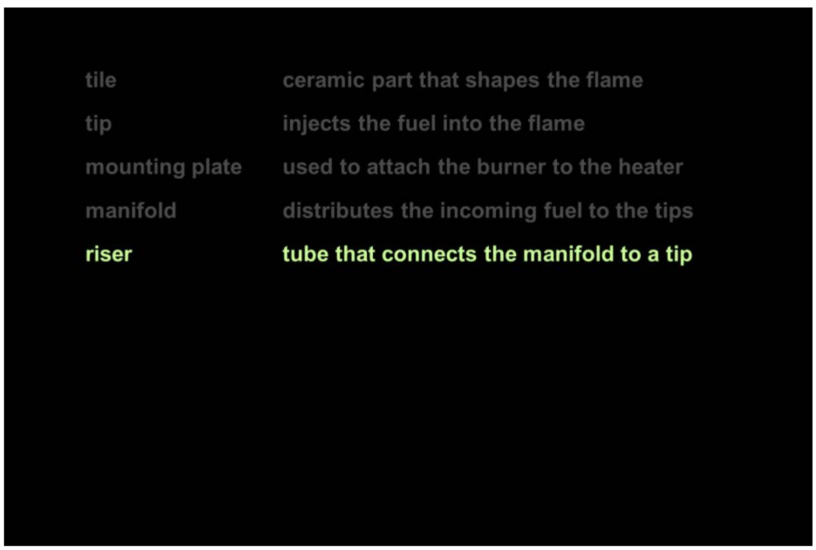


Figure 10. Label + description multimedia type with the labels + description that had already been displayed in dark gray and the current label + description (riser) in light green.

For the labels + narration multimedia type (see Figure 11), each label took a half second to display using the fade animation option in PowerPoint, followed by a half second delay, followed by narration which took five seconds, followed by a half second delay, and concluding with a half second for the label to be grayed out (where the text remained on the screen but the font changed to a dark gray as shown in Figure 12) for a total of seven seconds per component.

Each narration of the part description was done by the researcher in an essentially monotone voice due to the brevity of the descriptions and to minimize any biasing that might have occurred with different tones.

Figure 11. Label + narration multimedia type with all labels displayed.

Figure 12. Label + narration multimedia type with the labels that had already been displayed in dark gray and the current component (riser) in green.

Two types of static graphics were used in this study: a drawing and a photograph. Three types of instructional pictures have been identified: representational, analogical, and arbitrary (Alesandrini, 1984). Drawings and photographs are considered to be representational as they resemble the thing or concept they stand for.

For the drawing multimedia type, the drawings used to fabricate the actual burner (shown in Figure 15) were used to generate the image shown in Figure 13. The software used to create this drawing is called Creo Elements/Pro (formerly known as Pro/Engineer). The image created in this software to fabricate the actual burner is three-dimensional, so the drawing shown in Figure 13 is a two-dimensional image of a particular view of the burner. The specific view selected clearly shows all parts of interest, where other views would have blocked some of the parts from sight. As each label was revealed, the description was given under the image. When a label was grayed, its description was removed and replaced by the description for the next label being shown.

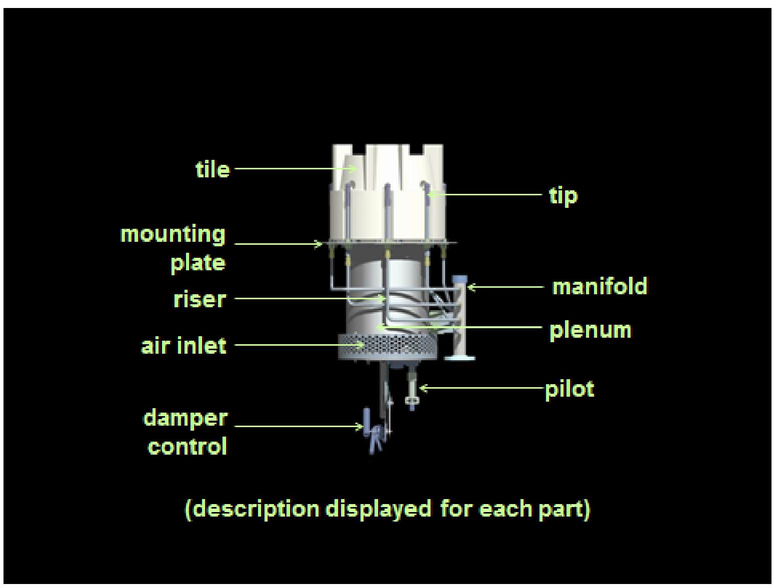


Figure 13. Drawing multimedia type with all labels displayed.

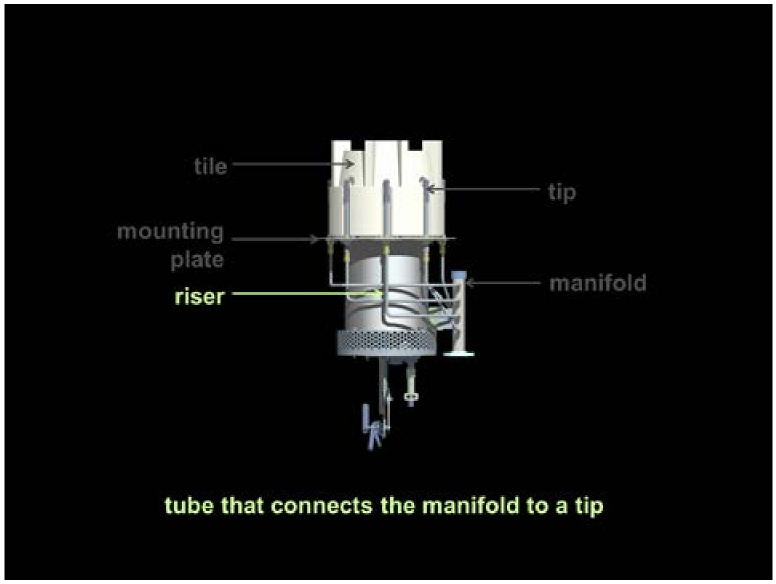


Figure 14. Drawing multimedia type with the labels and arrows that had already been displayed in dark gray and the current component (riser) in green.

For the photograph multimedia type (see Figure 15), a photograph of the actual burner was taken. The setup used to get the black background is shown in Figure 16. Adobe Photoshop was used to clean up the image to remove any unnecessary information that could have distracted the learner and biased the results. For example, the stand holding the burner had an identifying label that was removed and some information handwritten on the side of the burner was removed. Again, the labels and arrows that had already been shown remained on the screen but were changed to dark gray as shown in Figure 17.

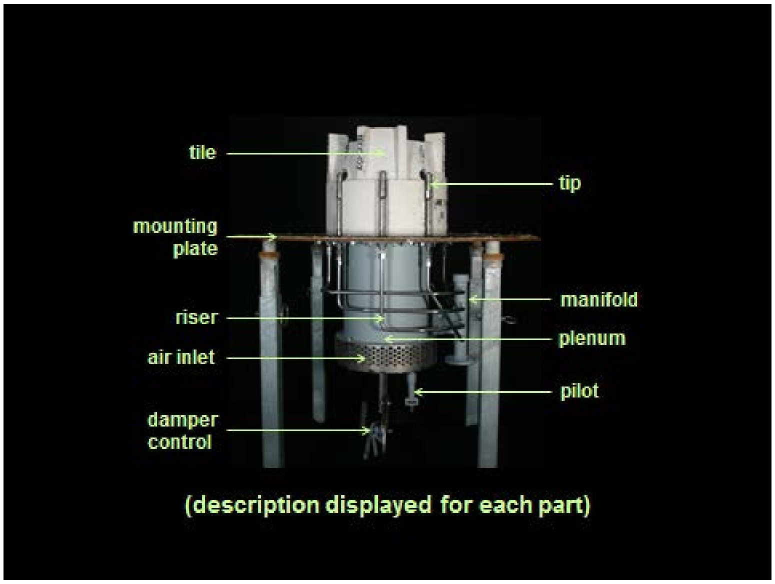


Figure 15. Photograph multimedia type with all labels displayed.

Figure 16. Setup used to take photographs of the burner.

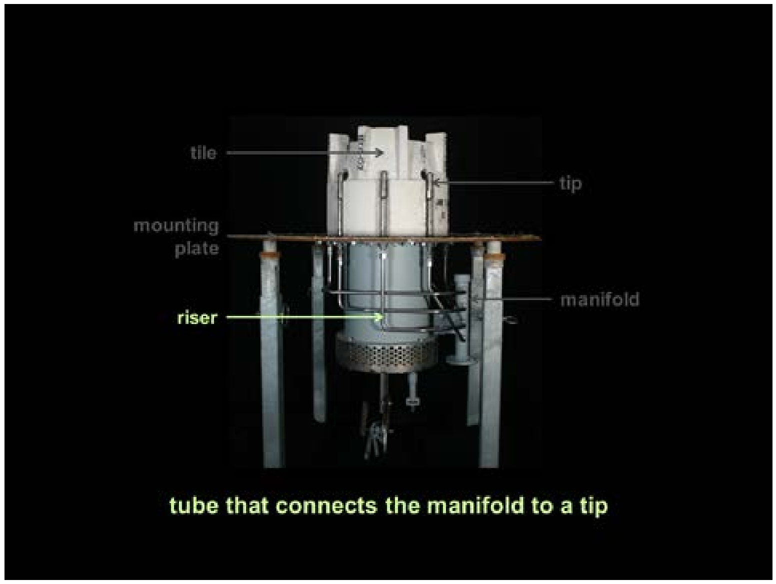


Figure 17. Photograph multimedia type with the labels and arrows that had already been displayed in dark gray and the current component (riser) in green.

For the animation multimedia type (see a screen capture in Figure 18), the burner rotated from right to left over a total of 59 sec. The animation was created using the same software (Creo Elements/Pro) used to generate the burner drawing shown in Figure 13. Only a single label and arrow pointing to a part along with the description below the image were shown at any given time. Unlike the text and static image multimedia types, labels and arrows were removed after they were shown and not kept on the screen in dark gray. This was because it would have been distracting to the viewer to have the image rotating with multiple labels and arrows on the screen in different colors, with the arrows changing lengths as the image rotated. The effective use of cueing is particularly important with animations because of their potential to create cognitive overload. Betrancourt (2005) called this the *attention-guiding principle* and recommended the use of, for example, arrows or highlighting, to guide learners viewing animations. Lin and Atkinson (2011) showed that learning was enhanced using educational animations with cueing compared to no cueing.

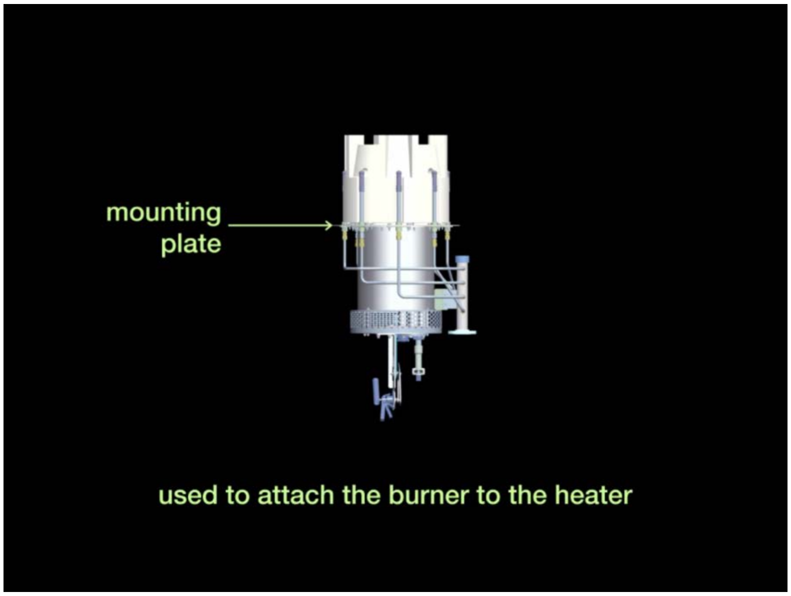


Figure 18. Screen capture of the animation multimedia type where the mounting plate was being shown.

For the video multimedia type (see a screen capture in Figure 19), the burner rotated from right to left over a total of 59 sec. This video was captured by manually rotating the burner stand on a heavy duty turntable. As for the animation multimedia type, only one label, arrow, and part description were shown at a time to reduce the cognitive load for the viewer.

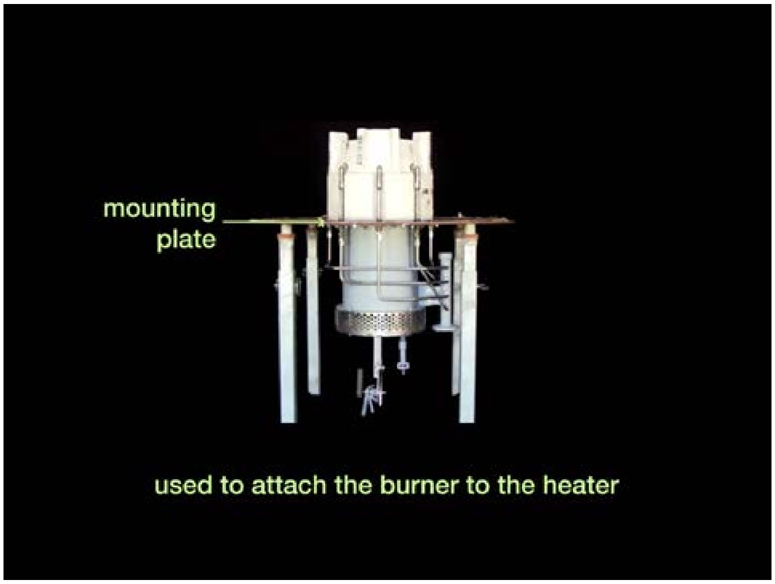


Figure 19. Screen capture of the video multimedia type where the mounting plate was being shown.

Both VR types were created with a software package called VR Worx 2.6 (http://vrtoolbox.com/) which is part of the VR Toolbox software suite. This software creates virtual reality simulations for objects by weaving together images taken at various angles looking at the object, where the camera remains fixed and the object is rotated (see Figure 20). Two limitations of the software were the image file size (maximum of about 0.5 MB) and the number of images (maximum of 36 or every 10°). The same setup shown in Figure 16 was used to take the photos where the burner was mounted on a heavy-duty turntable and rotated in 10° angles for a total of 36 images. Because each participant did not have a computer to view the VR simulations, screen capture software (Snagit) was used to build a video of a typical VR session.

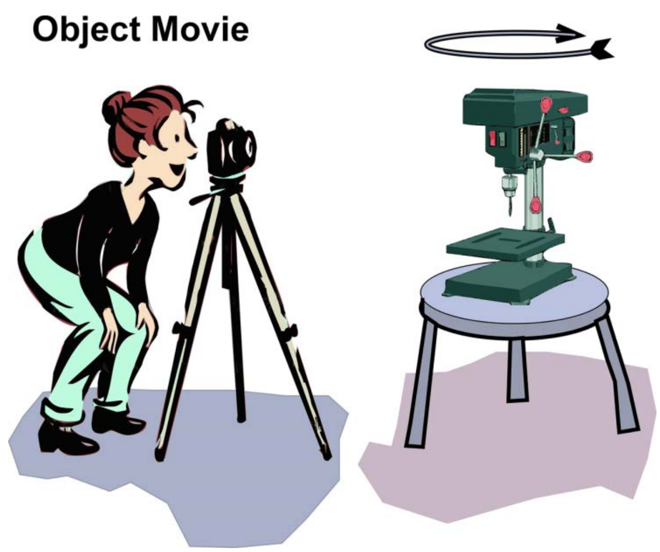


Figure 20. Setup for taking an VR object movie where the camera is fixed and the object rotated. Source: Floyd Ausburn, PhD, course instructional materials. Used by permission.

For the simulated VR type (see a screen capture in Figure 21), the simulation lasted for a total of 62 sec. The cursor (a small white hand) started at the right side of the screen and was dragged to the left across the screen which caused the image to rotate from right to left for the first 19 sec, which was the time it took for the cursor to be dragged across the entire screen. This displayed the first five parts (tile, tip, mounting plate, manifold, and riser). Then the cursor was moved, but not dragged (so the image did not rotate), back to the right side of the screen, which took approximately 2 sec. Then the cursor was again dragged across the screen from the right to the left for approximately 18 sec, which caused the image to again rotate from right to left and to display the remaining four parts (plenum, air inlet, pilot, and damper control) and briefly the very first part (tile) again to demonstrate to the viewer that all nine parts had been displayed and the image was back to the starting point. Then with the cursor at its location at the left side of the screen, it was dragged from left to right for approximately 10 sec. The parts were then shown in reverse order starting with the tile, then damper control, pilot, air inlet, and ending with the plenum. That segment was designed to show the viewer the capability of rotating the VR simulation in the opposite direction. The cursor was then moved down to the bottom center of the screen which took approximately 2 sec. The plus button was clicked to zoom into the image over approximately 4 sec. Figure 22 shows the image just prior to zooming and Figure 23 shows the image after the maximum zoom. Then, the minus button was clicked to zoom back out over about 3 sec. Finally, the cursor was moved back to the right center starting point over about 4 sec. A timeline of the actions is shown in Table 5.

Figure 21. Screen capture of the simulated VR multimedia type where the riser was being shown and the cursor (small white hand) was at the left of the screen after the first right to left rotation.

Figure 22. Screen capture of the simulated VR multimedia type just prior to zooming.

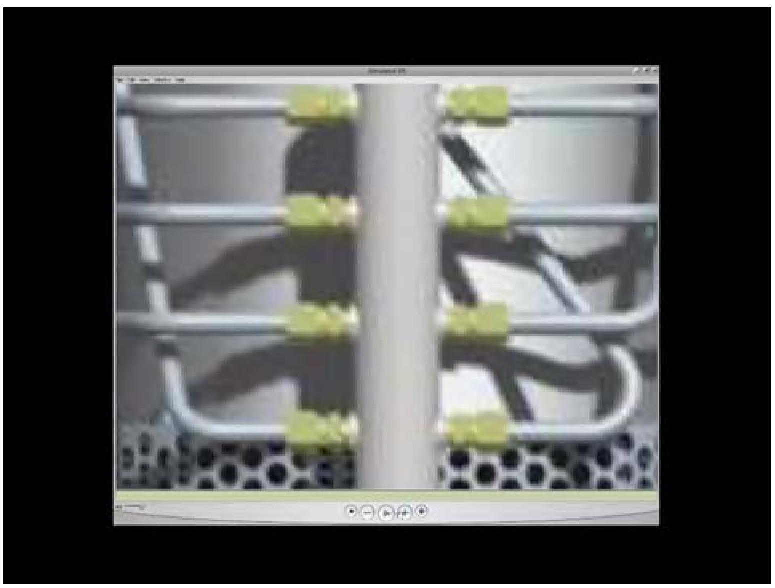


Figure 23. Screen capture of the simulated VR multimedia type with the maximum zoom.

Table 5

Timeline of the actions for the simulated VR multimedia type.

Simulation Time (sec)	Description
0	Rotate image from right to left
19	Move cursor back to the right hand side of the screen
21	Rotate image from right to left
39	Rotate image from left to right
49	Move cursor to bottom center of screen
51	Zoom in on burner
55	Zoom out of burner
58	Move cursor back to right center of screen
62	End of simulation

For the real VR type (see a screen capture in Figure 24), the simulation lasted for a total of 63 sec. The cursor (a small white hand) started at the right side of the screen and was dragged to the left across the screen which caused the image to rotate from right to left for the first 16 sec, which was the time it took for the cursor to be dragged across the entire screen. This displayed the first five parts (tile, tip, mounting plate, manifold, and riser). Then the cursor was moved, but not dragged (so the image did not rotate), back to the right side of the screen, which took approximately 2 sec. Then the cursor was again dragged across the screen from the right to the left for approximately 15 sec, which caused the image to again rotate from right to left and to display the remaining four parts (plenum, air inlet, pilot, and damper control) and briefly the very first part (tile) again to demonstrate to the viewer that all nine parts had been displayed and the image was back to the starting point. Then with the cursor at its location at the left side of the screen, it was dragged from left to right for approximately 13 sec. The parts were then shown in reverse order starting with the tile, then damper control, pilot, air inlet, and ending with the plenum. That segment was designed to show the viewer the capability of rotating the VR simulation in the opposite direction. Then the cursor was moved down to the bottom center of the screen in approximately 2 sec. The plus button was clicked to zoom into the image over approximately 4 sec. Figure 25 shows the image just prior to zooming and Figure 26 shows the image after the maximum zoom. Then the minus button was clicked to zoom back out over about 3 sec. Finally, the cursor was moved back to the right center starting point over about 6 sec. A timeline of the actions is shown in Table 6.

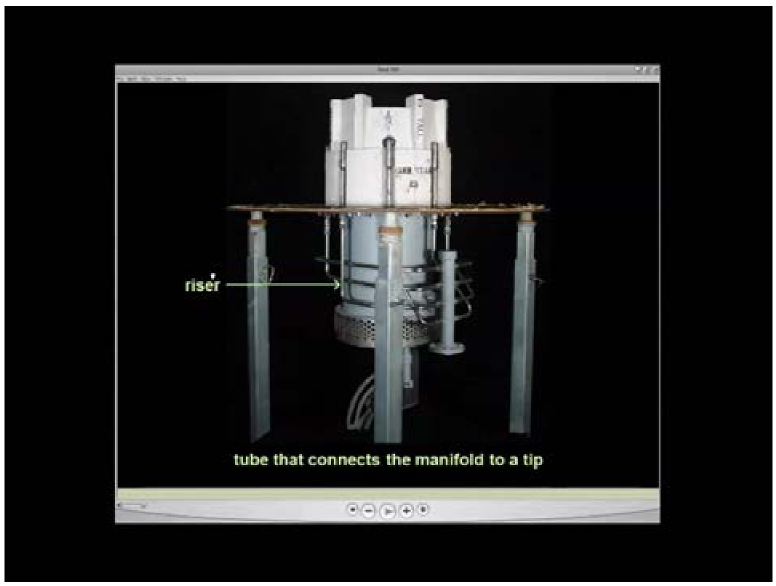


Figure 24. Screen capture of the real VR multimedia type where the riser was being shown and the cursor (small white hand just above the word riser) was at the left of the screen after the first right to left rotation.

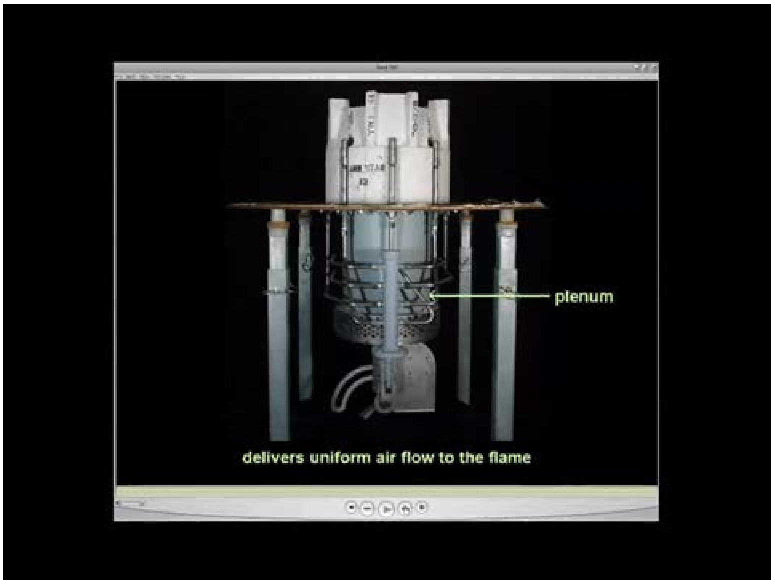


Figure 25. Screen capture of the real VR multimedia type just prior to zooming.

Figure 26. Screen capture of the real VR multimedia type with the maximum zoom.

Table 6

Timeline of the actions for the real VR multimedia type.

Simulation Time (sec)	Description
0	Rotate image from right to left
16	Move cursor back to the right hand side of the screen
18	Rotate image from right to left
33	Rotate image from left to right
46	Move cursor to bottom center of screen
48	Zoom in on burner
52	Zoom out of burner
57	Move cursor back to right center of screen
63	End of simulation

Procedures

Oklahoma State University Institutional Review Board approval for this research was received on March 4, 2013 (see Appendix D). Participants were invited to the sessions based on their availability according to John Zink's Microsoft Outlook computerized calendar. The Participant Invitation included with the Outlook invitation is shown in Appendix D. Participants were free to attend or not at their own discretion. The Informed Consent given to each participant is shown in Appendix D.

Phase 1

Phase 1 was administered over two consecutive work days (a Friday and the following Monday), with two sessions over lunch each day (see Table 7). There were a total of 86 participants who took the Phase 1 survey, with 48 (56% of the total) taking the A version and 38

(44% of the total) taking the B version. Participants were asked to sign in as they entered the room, so the researcher would know who participated so they would not be asked again to complete the same survey. However, the surveys themselves were completely anonymous.

The room arrangement is shown in Figure 27. Lunch consisting of sandwiches, chips, drinks, and cookies were provided to the participants at the back of the room. After participants got their lunch, they sat at tables already containing a package of information including a copy of the Participant Invitation, the survey, and a blue double-sided sheet containing the ATLAS instrument. The tables were arranged in five rows facing the screens, with eight seats across each row for a maximum capacity of 40 participants. There were an equal number of seats on either side of the room. Participants could sit wherever there was a package of information, so they were not directed to sit in any particular location. The very last row in the room was not used in any of the sessions as it was somewhat far away from the screens which might have biased the results. Depending on how many people accepted the invitation for a given session, information packages were arranged as close to the center of the room as possible. For smaller sessions, the first row was not used to try to give participants a better angle to view both screens. The viewable area of each screen was 8 ft-8 in. wide by 5 ft-2 in. high.

Table 7

Phase 1 survey sessions.

Date	Time	Version	# Participants
07/26/2013 (Friday)	11:30 AM	A	26
	12:30 PM	A	22
			48
07/29/2013 (Monday)	11:30 AM	B	32
	12:30 PM	B	6
			38
			86

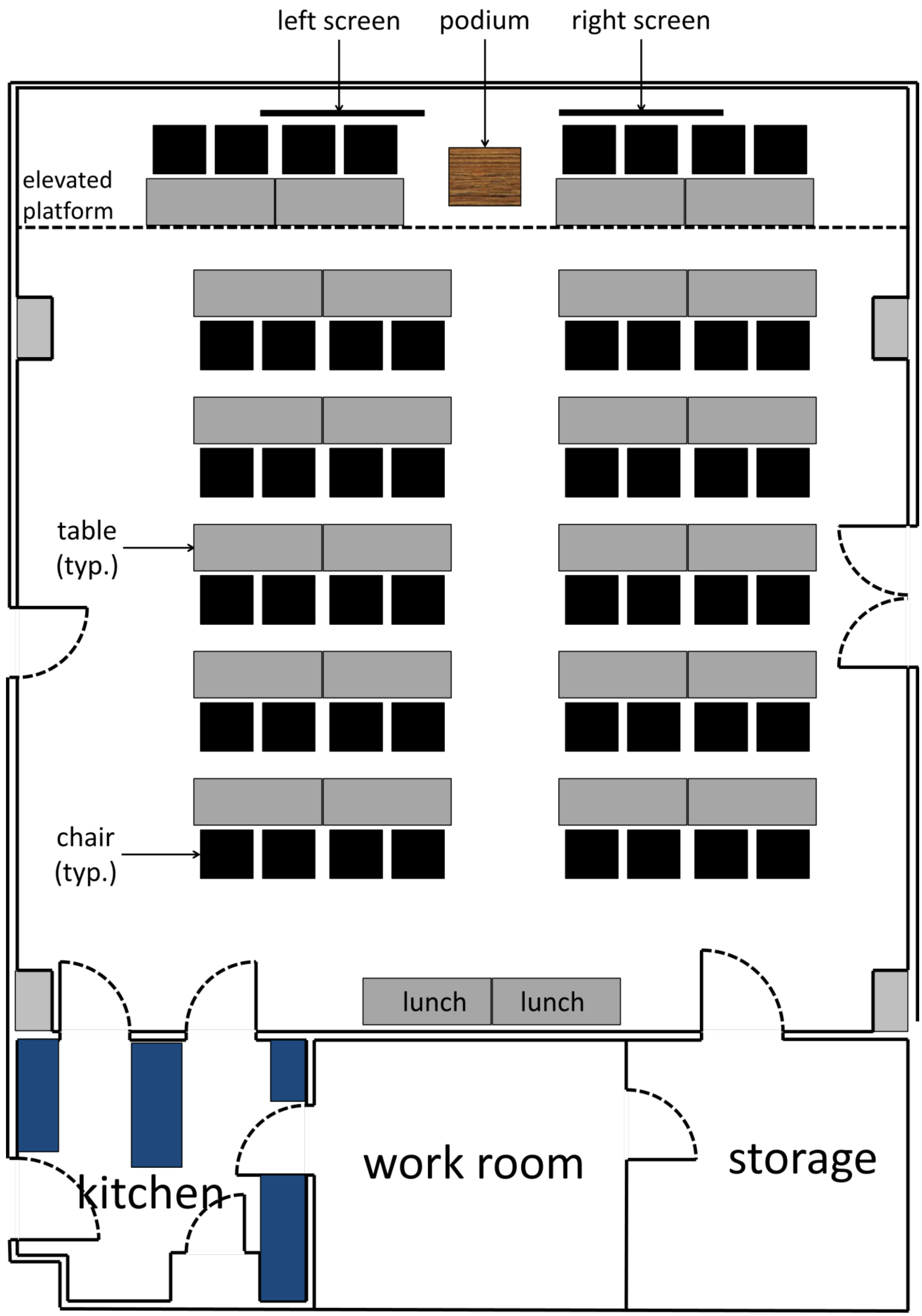


Figure 27. Room arrangement used for the sessions.

The researcher stood behind the podium in the front center of the room where both computers were located containing the PowerPoint slides (see Figure 28). A different presentation was loaded onto each computer, so the proper multimedia types would appear on the left and right screens (as viewed by the participants, not by the researcher who was facing the participants with his back to the screens), depending on which survey was being shown (see Table 2 for the slide arrangements used for each version of the Phase 1 survey). The slides were manually advanced by the researcher based on a visual observation of the participants to determine when everyone had completed the given section of the survey.

Figure 28. Researcher presenting instructions during a survey session.

An introduction slide (see Figure E1 in Appendix E) was shown on both screens until the start of the survey. After a very brief introduction thanking the subjects for participating, slide two was shown which had some background information on the survey. The slides and PowerPoint animation builds were manually advanced by simultaneously pushing the down arrow buttons on the keyboards for both computers. The first bullet item on slide two (see Figure E2) reminded the participants that the survey was completely voluntary and anonymous and that it had been approved by the company's senior management, legal department, and human resources department. The second bullet on slide two (see Figure E3) told the participants that turning in their surveys indicated they were consenting to participate in the survey. Bullet three on slide two (see Figure D4) gave the two primary purposes of the survey: "Design more effective JZ Institute courses" and "Determine if there are any correlations between demographic data & multimedia preferences to possibly customize online courses to learners." The first bullet on slide three (see Figure E5) explained why the survey was being conducted in two phases: "28 possible combinations of pairs among 8 multimedia types – too many to compare in 1 sitting." The second major bullet on slide three (see Figure E6) explained Phase 1 including the approximate length (30 minutes) and the data that were going to be collected (demographics, learning strategy preference, verbal-visual preference, and preferences within multimedia types). The third major bullet on slide three (see Figure E7) explained Phase 2 which was expected to be conducted within the next few weeks and included the expected length (15 minutes) and the data to be collected (preferences between multimedia types).

Slide four gave instructions on how to complete pages two and three of the survey. The first major bullet on slide four (see Figure E8) asked the participants to complete the Participant ID# on page one of the survey. That would be used to connect the Phase 1 and Phase 2 surveys so Phase 1 participants would not have to fill out the demographic, prior knowledge, learning strategy preference, and verbal-visual preference information again for Phase 2. The second major bullet on slide four asked the participants to complete the demographic data on page two of the survey (see Figure E9). The third major bullet on slide four asked the participants to complete their knowledge of the COOLstar ARIA burner at the top of page two of the survey (see Figure E10). The fourth major bullet on slide four asked the participants to complete the Learning Strategy Preference in the middle of page three of the survey (see Figure E11). This included using page one of the ATLAS instrument to find their strategy and marking it in the middle of page three of the survey, reading the descriptions of their strategy on page two of the ATLAS instrument, and then indicating the degree to which they agreed with the selected strategy on the middle of page three of the survey. The fifth and last major bullet on slide four asked the participants to indicate their verbal-visual preference at the bottom of page three of the survey (see Figure E12).

Slide five provided instructions for how to fill out the multimedia preferences section of the survey. Text was shown first (see Figure E13) which discussed the three types of information that would be requested when comparing multimedia types. Next, the method that would be used to specify preference was shown (see Figure E14). Finally, the method that would be used to rate and rank multimedia types was displayed (see Figure E15). The participants were then asked if they had any questions about the instructions.

Slide six introduced the first multimedia pair (see Figure E16). There was a note preceding the slide that contained narration to alert the participants that the audio they would hear only applied to that slide and not to the slide on the other screen. In survey 1A, this was the left slide and in 1B it was the right slide. Slide seven showed the first multimedia pair. Figure E17 shows the display about halfway through the pair and Figure E18 shows the pair after the display was completed. Slide eight (see Figure E19) then instructed the participants to complete page four of the survey for their preference, rating, and ranking for multimedia pair one.

This was repeated for multimedia pairs two, three, and four (see Figure E20 through Figure E30). There was a special note before the photograph which said “the 4 vertical legs in the following photo are part of the stand holding the burner & not part of the burner itself.” This was to explain to the viewers a significant difference when comparing the drawing and the photo. There was also a special note on slide 16 before displaying the virtual reality types (see Figure E28). The note said “The next slide is a screen capture of a virtual reality simulation. The user can rotate the image in either direction and can zoom in and out. The small hand is the cursor showing a user manipulating the image.” The researcher then explained to the participants that they should imagine they had a computer and could manipulate the virtual reality simulation themselves.

The typical time to complete the Phase 1 survey was approximately 15 minutes (half the expected 30 minutes). Participants were instructed to give their completed surveys to assistants helping the researcher (see Figure E31), so the researcher did not know who turned in which survey. After turning in their surveys, participants were offered a small gift (a company promotional item under $10) as thanks for their participation and to encourage them to participate in the Phase 2 survey. The participants were not told in advance they would be offered a gift for participating.

Phase 2

After the Phase 1 results were analyzed, the most preferred slides in each category were selected for Phase 2, which was designed to measure preferences *between multimedia categories*. Phase 2 was conducted as soon as possible after Phase 1. There were a total of 110 participants who took the Phase 2 survey, with 56 (51% of the total) taking the C version and 54 (49% of the total) taking the D version. Of the 110 participants, 78 (71% of the total) took the Phase 1 survey and 32 (29% of the total) did not. Only eight Phase 1 participants did not take the Phase 2 survey due to travel schedules and work conflicts.

The data were collected over about a three week period as shown in Table 8, although more than half of the responses (58 or 53% of the total) were received two days after the conclusion of Phase 1. There was a one week gap in collecting data as the room with two screens was not available during that time. Participants were asked to sign in as they entered room, so the researcher would know who participated so they would not be asked again to complete the same survey. However, the surveys themselves were completely anonymous.

Table 8

Phase 2 survey sessions.

Date	Time	Version	# Participants
07/31/2013 (Wednesday)	10:30 AM	C	30
	1:30 PM	D	28
			58
08/02/2013 (Friday)	11:00 AM	D	5
	1:30 PM	D	13
			18
08/12/2013 (Monday)	9:30 AM	C	18
08/16/2013 (Friday)	1:30 PM	D	8
08/19/2013 (Monday)	3:30 PM	C	8
			110

The room arrangement was the same as in Phase 1 (see Figure 27). In Phase 2, only snacks (e.g., fruit, nuts, chips, cookies, and/or brownies) and drinks were provided instead of lunch as in Phase 1. It was discovered after talking to some who did and did not participate in Phase 1 that having the sessions over lunch was not preferred, as some people have specific things they like to do at lunch. Not scheduling over lunch improved the overall response rate for Phase 2 compared to Phase 1. After participants got their snack, they sat at tables already containing a package of information including a copy of the Participant Invitation, the survey, a blue double-sided sheet containing the ATLAS instrument, and a list of the Participant ID numbers from Phase 1. Participants could sit wherever there was a package of information, so they were not directed to sit in any particular location. The very last row in the room was not used in any of the sessions as it was somewhat far away from the screens. Depending on how many people accepted the invitation for a given session, information packages were arranged as close to the center of the room as possible. For smaller sessions, the first row was not used to try to give participants a better angle to view both screens, which were the same as used in Phase 1.

The researcher stood behind the podium in the front center of the room where both computers were located containing the PowerPoint slides (see Figure 28). A different presentation was loaded onto each computer, so the proper multimedia types would appear on the left and right screens (as viewed by the participants, not by the researcher who was facing the participants with his back to the screens), depending on which survey was being shown (see Table 3 for the slide arrangements used for each version of the Phase 2 survey). The slides were manually advanced by the researcher based on a visual observation of the participants to determine when everyone had completed the given section of the survey.

The same introduction slide used in Phase 1 (see Figure D1) was shown on both screens until the start of the survey. After a very brief introduction thanking the subjects for participating, the same slide two used in Phase 1 (see Figure D4) was shown which had some background information on the survey. The slides and PowerPoint animation builds were manually advanced by simultaneously pushing the down arrow buttons on the keyboards for both computers. Slide three from Phase 1, which explained why there were two phases, was not used in Phase 2.

Slide three gave instructions on how to complete pages two and three of the survey. It was the same as used in Phase 1, except a new bullet point was added at the top of the slide (see Figure F1 in Appendix F) which read “If you remember your Phase 1 Participant ID# and it is on the list, skip pages 2 & 3.” A list of Participant ID numbers used in Phase 1 was given to the participants to make sure that if they completed Phase 1, that the Participant ID# they would be using in Phase 2 matched an ID# from Phase 1. This was because not every Phase 1 participant used the recommended numbering scheme (and they were not required to do so). For example, a few participants used their last name because they were not concerned about anonymity and wanted to make sure they would easily remember their Participant ID#. If a Phase 2 participant would have used a Participant ID# that was not used in Phase 1 and skipped pages two and three of the survey as they were instructed to do, then they would only have completed the multimedia preferences section and there would be no demographic data, learning strategy preference, or verbal-visual preference to match with their multimedia preferences. In successive Phase 2 sessions, the list of “available” Participant ID numbers from Phase 1 was reduced as they were used in earlier Phase 2 sessions, to avoid accidentally having the same number used more than once. Participants that could not remember their Phase 1 Participant ID# or could not match theirs with any of those on the list, along with those participants who did not take the Phase 1 survey, were asked to complete pages two and three of the Phase 2 survey.

Slide four provided instructions for how to fill out the multimedia preferences section of the survey. Text was shown first (see Figure E13) which discussed the three types of information that would be requested when comparing multimedia types. Next, the method that would be used to specify preference was shown (see Figure E14). Finally, the method that would be used to rate and rank multimedia types was displayed (see Figure E15). The participants were then asked if they had any questions about the instructions.

Slide five introduced the first multimedia pair of Phase 2 (see Figure F2), which was actually Multimedia Pair #5 because four pairs were used in Phase 1. Slide six showed the first multimedia pair. Figure F3 shows the pair after both slides were completely displayed. Unlike in Phase 1 which used a separate slide (see Figure E19 for example) to instruct the participants to complete page four of the survey for their preference, rating, and ranking for multimedia pair one, this note was included on the multimedia slides. It was thought this would help the participants in case they wanted to refer to the slides again while filling out the comparisons for a given pair of multimedia types.

This was repeated for multimedia pairs six through ten (see Figure F4 through Figure F13). As in Phase 1, there was the special note (see Figure E28) before displaying the first occurrence of the simulated virtual reality type which said “The next slide is a screen capture of a virtual reality simulation. The user can rotate the image in either direction and can zoom in and out. The small hand is the cursor showing a user manipulating the image.” The researcher then verbally explained to the participants that they should imagine they had a computer and could manipulate the virtual reality simulation themselves.

Unlike Phase 1, there was also a final comparison of all four Phase 2 multimedia types. The introductory slide for the overall comparison is shown in Figure F14. It was then verbally explained what the participants would see next which would be two multimedia types on the left screen and two on the right. Going from the participants’ left to right, these would be identified as *Left slide, left image*; *Left slide, right image*; *Right slide, left image*; and *Right slide, right image*. Those labels appeared at the bottom of the screen as shown in slide 19 (see Figure F15). The order of the multimedia types was partially random, but partially ordered. Because two of the types were static and two were dynamic, one of each was put on each screen to avoid having two moving on the same screen which might have biased the results.

The typical time to complete the Phase 2 survey was approximately 15 minutes (about what was initially expected). It would have been faster except there were some participants in each session who had not completed the Phase 1 survey, so they needed to complete the demographics, prior knowledge, learning strategy preference, and verbal-visual preference. Participants were instructed to give their completed surveys to assistants helping the researcher (see Figure F16), so the researcher did not know who turned in which survey. After turning in their surveys, participants were offered a small gift (a company promotional item under $10, different than that given in Phase 1) as thanks for their participation. The participants were not told in advance they would be offered a gift for participating.

Data Analysis

Statistical Analysis

The frequency data collected in this study were categorical. Some were ordinal (e.g., age range, total years of work experience range, and total years of work experience at John Zink range). Others were nominal (e.g., gender and degree). The appropriate statistical analysis for these types of data is chi-square which compares distributions of observed frequencies with expected frequencies (Wickens, 1989). These inferential statistical tests are nonparametric (Sheskin, 2011). Three assumptions must be met for a valid interpretation (Ary, Jacobs, Razavieh, & Sorensen, 2006). The first is that the observations must be independent where the subjects in each sample were randomly and independently selected. The second assumption is that the categories are mutually exclusive where each observation appears in one and only category in the table. The third assumption is that the observations were measured as frequencies. With the exception of random selection of subjects, these assumptions were met in the present study. The software package IBM SPSS Statistics version 22.0.0.0 (SPSS, 2013) was used here to analyze the data. The level of statistical significance used in this study was $p < .05$.

Missing Data Handling

Missing data are a common problem in quantitative educational research studies (Peugh & Enders, 2004). This study included two types of missing data: item nonresponse and participant attrition (Schlomer, Bauman, & Card, 2010). In the former, participants complete a survey but do not give a response to every item. That was the case in this study and the missing responses will be discussed individually as they occurred in the reported findings. In the latter case, some participants are lost in a longitudinal or multiple session study, which was the case here where not all participants completed both surveys.

There were a total of 118 participants. Thirty-two participants that completed the Phase 2 survey did not complete the Phase 1 survey. No attempt was made in Phase 1 to maximize participation as an important consideration in this study was completing the survey as quickly as possible to minimize information loss and participant diffusion between the phases. Eight participants that completed the Phase 1 survey did not complete the Phase 2 survey. In Phase 2, considerable effort was made to maximize participation as the results of this phase were the main focus of the study. Even if participants did not complete both phases, they were still asked to complete the demographics, prior knowledge, and learner preferences sections. Therefore, the main sources of missing data were for preferences within a multimedia type (Phase 1) and between multimedia types (Phase 2).

Most quantitative education research studies contain missing data (Gemici, Rojewski, & Lee, 2012). There is no consensus regarding how much missing data, which also includes unintelligible data (Schafer & Graham, 2002), is problematic. For example, Schafer (1997), Bennett (2001), and Peng, Harwell, Liou, and Ehman (2007) recommended 5%, 10% and 20%, respectively as the cutoff. Others (e.g., Schlomer et al., 2010) suggest that it is not the percentage of missing data that is important but rather the adequacy of the statistical power of the resulting dataset and the pattern of the missing data. It is also important to distinguish between missing data patterns and missing data mechanisms (Enders, 2010).

Statisticians categorize missing data according to Little and Rubin’s (1987) classifications: missing completely at random (MCAR), missing at random (MAR), and not missing at random (NMAR). For MCAR data, there are no missing data patterns and the randomly missing data are not related to any variables being studied. The missing data can be considered as a random sub-sample of the dataset. Unfortunately, it is generally very difficult to determine if missing data are MCAR. A better term for MAR might be conditionally missing at random (Graham, 2009). MAR data are similar to MCAR except MAR data are related to another variable in the data set but not to the variable of interest. Both the MCAR and MAR missing data mechanisms can be ignored in the analysis process (Allison, 2009; Bennett, 2001). In NMAR, the missing data are related to the variable of interest and can't be ignored in the analysis process. For continuous variables, there is a test for MCAR (Little, 1988), but not for MAR or NMAR (Gemici et al., 2012).

There are various approaches for handling missing data. In listwise deletion (also called complete case analysis or case reduction), any cases with any missing data are completely eliminated which can result in considerable data loss. In pairwise deletion (also called available case analysis), cases are deleted where data are missing for a variable of interest. However, these cases are used for other variables where data are available. There are also many methods for substituting plausible data for missing data, which is called *imputation*. For example, in mean substitution the missing values are imputed with the mean value for the variable of interest. In regression substitution, missing values are predicted based on other variables that are not missing using a regression analysis. In pattern-matching imputation (sometimes called hot-deck imputation), missing values are replaced with values from other similar cases without missing data. In a similar approach called cold-deck imputation, missing data are replaced with data based on information outside of the dataset, such as from results of previous similar research. There are also stochastic imputation methods such as stochastic regression, expectation maximization, multiple imputation, Markov-chain imputation, full information maximum likelihood, and raw maximum likelihood (Bennett, 2001; Gemici et al., 2012; Schlomer et al., 2010).

Bodner (2006) offered the following five recommendations for handling missing data in publications:

1. Report sample sizes and degrees of freedom for all inferential tests.
2. Discuss the presence, extent, and nature of incomplete data.
3. Explore the pattern of missing data and provide reasons for the missing data.
4. Discuss how data were analyzed with the existence of missing data.
5. Discuss results in light of the uncertainties caused by the missing data.

These recommendations were followed in the present study as well as possible.

Table G1 in Appendix G shows the number and percentage of missing data for the demographic and learner preferences data. The most missing data were for degree specialty (3.4%). For most variables, the missing data were less than 2% of the sample. Table G2 shows the pattern of missing data where the cases have been sorted based on the variables going from left to right using gender, age, and total work experience. In the last case in the table, the participant did not fill out the demographics or learner preferences and only provided their multimedia preferences. While there is a test for MCAR continuous missing data, there is none currently for categorical missing data (Enders, 2010). Therefore, visual observation must be used to assess the missing data pattern. The data in Table G2 appeared to the researcher to be at least MAR as no obvious pattern was apparent. The missing data appeared to be approximately randomly distributed. The cases with missing data were generally in similar proportions to the overall survey. For example, one of the eight cases (12.5%) with missing data was for a female participant which compares to 12.6% females in the population and 15.3% in the sample. However, this was not true for all variables. For example, the cases with missing data only occurred for two age ranges (one case was missing the age range): 46-55 and 56-65. While these represented significant portions of the sample, they were not nearly as high as in the missing data.

Phase 2 was the focus of this study. Table G3 shows the eight Phase 1 participants (all males) who did not participate in the Phase 2 survey, sorted by age range, total work experience, and John Zink work experience. Most of the variables were generally in similar proportion to the sample, although there were a disproportionate number of electrical engineers (62.5% of the missing cases compared to 16.1% of the sample) who did not participate in Phase 2. Table G4 shows the learning strategy, verbal-visual, and multimedia preferences for the same eight Phase 1 participants who did not participate in Phase 2, sorted by learning strategy preference and then by verbal-visual preference. These data were generally similar to the preferences for the Phase 2 sample.

Because the percentage of missing demographics and learner preferences (see Table G1) were small (3.4% maximum) and the eight Phase 1 participants who did not participate in Phase 2 were generally similar to the sample, pairwise deletion was used in this study to account for the missing data to maximize the available data without significantly biasing the results.

Calculation Procedures

Phase 1.

To determine the preferred multimedia type in a pair, three different methods were used: relative preference, rating and ranking. In the relative preference method, the left multimedia type was preferred if the participant selected *Strongly prefer left slide*, *Moderately prefer left slide*, or *Slightly prefer left slide*. The right multimedia type was preferred if the participant selected *Strongly prefer right slide*, *Moderately prefer right slide*, or *Slightly prefer right slide*. No attempt was made in Phase 1 to calculate the strength of the preference (e.g., moderately prefer is a stronger preference than slightly prefer). No preference was assigned if the participant selected *No preference*. The preferred multimedia type in the rating method was the type that received the higher relative rating. No preference was assigned if both types in a comparison received the same rating. The preferred multimedia type in the ranking method was the type that received a one. For a given multimedia pair, a mean preferred type was calculated using all three methods. This normally would be the same type using all three methods, although there were some cases where a fractional mean resulted because a participant selected different preferred types using the different methods. No data were eliminated if a participant selected one multimedia type with two of the methods and the other type with the third method.

The overall preferred multimedia type within each category was determined using the ratings and rankings. The ratings were normalized to values between zero and one so they could be directly compared. The rating points for a given type within a category were calculated based on its fraction of the total rating points given by the participant. For example, if a participant gave one type 25 points and the other type 75 points, then the first type would have a normalized rating of 25 / (25 + 75) = .25 and the other type would have a normalized rating of 75 / (25 + 75) = .75. Then, the preferred type in each category was the one that received the most rating points. For the ranking method, a type was given points according to its ranking in the pair. The type ranked highest received one point and the type ranked lowest received two points. Then, the preferred type in each category using the ranking method was the one that received the least ranking points.

Phase 2.

The calculations to determine the preferred multimedia types in Phase 2 were slightly different than those in Phase 1, because each of the remaining four types considered in Phase 2 was separately compared against the other three remaining types. Rather than one preference, rating, and ranking for each type, there were three. This was the result of comparing four types in pairs where the arrangement doesn’t matter (e.g., doesn’t matter if a multimedia type is on the left or the right in a pairwise comparison) for a total of six pairwise comparisons. In addition, in Phase 2 there were also final overall rating and ranking of the four multimedia types which were not included in Phase 1. Therefore, five different comparisons were made to determine the relative preferences for the four different multimedia categories investigated in this study: pairwise preferences, pairwise ratings, pairwise rankings, overall rating, and overall ranking.

As in Phase 1, for a given pairwise comparison, there was a preference, rating, and ranking. In theory, if a participant preferred one type over another, this should have been reflected in all three comparison methods. However, there were some discrepancies where a participant may have preferred one type in a pair with one or two of the comparison methods, but the other type in the other comparison methods. Again, no comparison data were eliminated even if there was such a discrepancy.

In a pairwise comparison in Phase 2, preference points were given to the preferred multimedia type based on the strength of the preference. If it was *Strongly preferred*, *Moderately preferred*, or *Slightly preferred*, it received three, two, or one points, respectively. The other type in the pair did not receive any points. If there was no preference between the two types, neither received any points. A mean value was calculated for each type in a pairwise comparison. Means were used, instead of total points, because there were different numbers of comparisons for each pair as some participants did not give a comparison for some of the pairs (i.e., missing data). Then, the three mean values from the three pairwise comparisons for each multimedia type were summed together. These total values were then normalized by dividing them by the highest total mean. Therefore, the most preferred would have a normalized score of one and the rest would be between zero and one. The higher the normalized mean, the more preferred the type.

In the pairwise ratings, the ratings were normalized by dividing the individual ratings by the total amount of rating points given by the participant for that pair. For example, if one type in a pair was given a rating of 50 and the other type in the pair was given a rating of 100, then the first type would have a normalized rating of 50/(50+100) = .33 and the other type would have a normalized rating of 100/(50+100) = .67. The mean was calculated using the normalized ratings for each pair, rather than summing them, because there were different numbers of ratings as some participants did not rate every pair. The three mean values for the three pairwise comparisons for each multimedia type compared in Phase 2 were added together to get a total pairwise rating.

These values were then normalized by dividing them by the highest total mean. Therefore, the multimedia type with the highest rating would have a normalized score of one and the rest would be between zero and one. The higher the mean, the more preferred the type.

A similar procedure was used to compare the pairwise rankings for each of the four categories. A relative ranking was calculated for each pairwise comparison. No normalization of the raw scores was required as all participants used the same ranking method (either a one or a two). A mean ranking was determined for each type in each pair, again because not every participant ranked every pair. The three mean values for the three pairwise comparisons for each multimedia type were added together to get a total pairwise ranking. These values were then normalized by dividing the lowest total mean pairwise ranking (i.e., highest ranked multimedia type) by each total mean. That inverted the ranking scores so they could be directly compared with the preference and rating scores. Therefore, the multimedia type with the highest ranking would have a normalized score of one and the rest would be between zero and one. The higher the total pairwise ranking mean, the more preferred the type.

In the overall comparison of all four Phase 2 multimedia types, the ratings were normalized by dividing each participant's individual ratings by their total rating points. Then a mean rating was determined for each type. The four overall mean ratings were then normalized by dividing each by the highest overall mean rating. Then, the multimedia type with the highest overall rating would have an overall normalized mean rating of one and the other three would have values between zero and one. The higher the normalized overall mean rating, the more preferred the type.

For the overall ranking comparison, a mean ranking was determined for each type. Again, no normalization of the raw scores was required as the same ranking method was used by all participants (one = highest through four = lowest). The lower the mean ranking, the more preferred the type. These rankings were then converted to scores that could be compared to the preferences and ratings, where higher values mean more preferred. The rankings of one, two, three, and four were converted to normalized rankings of 1.00, .75, .50, and .25, respectively, where uniform spacing between rankings was assumed. The mean was then calculated for each type. The mean values were then normalized by dividing each by the highest mean value (i.e., the most preferred multimedia type). Then, the most preferred would have a normalized value of one and the other three would have normalized values between zero and one.

After normalization, all five methods produced values between zero and one, where the higher the mean the more preferred the multimedia type. Then, the mean values for all five methods of comparing the Phase 2 types were calculated, rather than using summations, because there were different numbers of participants for each method. Using a mean value, rather than a weighted mean, assumes that no method of comparison was superior or inferior to another.

CHAPTER IV

FINDINGS

This chapter reports the findings of the study. Primary statistical analyses included descriptive statistics and chi-square tests of expected and observed frequency distributions for categorical data. Missing data were handled using the pairwise deletion method.

Demographics

Table 9 shows that the majority of the participants were male although there were more females in the sample than in the population.

Table 9

Participants' gender in the population and the sample.

	Population		Sample	
Gender	*N*	Percent	*N*	Percent
Female	22	12.6	18	15.3
Male	152	87.4	98	83.1
Missing	0	.0	2	1.7
Total	174	100.0	118	100.0

Figure 29 (data from Table H1 in Appendix H) shows most participants were in the 26 to 65 age range and were fairly evenly distributed in the four ranges for that span. No data were provided by the Zink HR department for the age range distribution of the population.

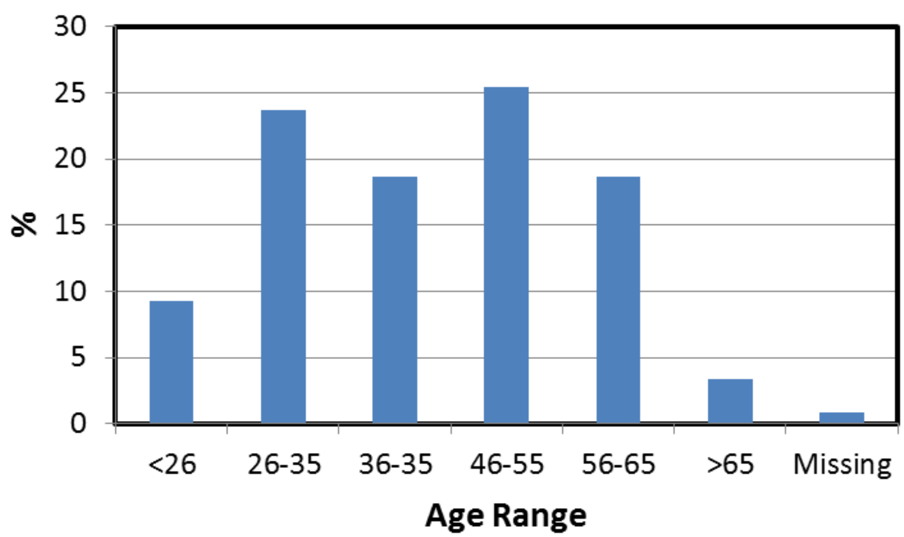


Figure 29. Age range distribution of the participants.

Figure 30 (data from Table H2) shows that both the total years of work experience and the years of work experience at John Zink were somewhat bimodally distributed, with more participants with either a little or a lot of experience, and comparatively fewer with intermediate experience. No data were provided by HR on the distributions for the population, although this bimodal distribution of experience is a recognized condition at the company and in the industry as a whole.

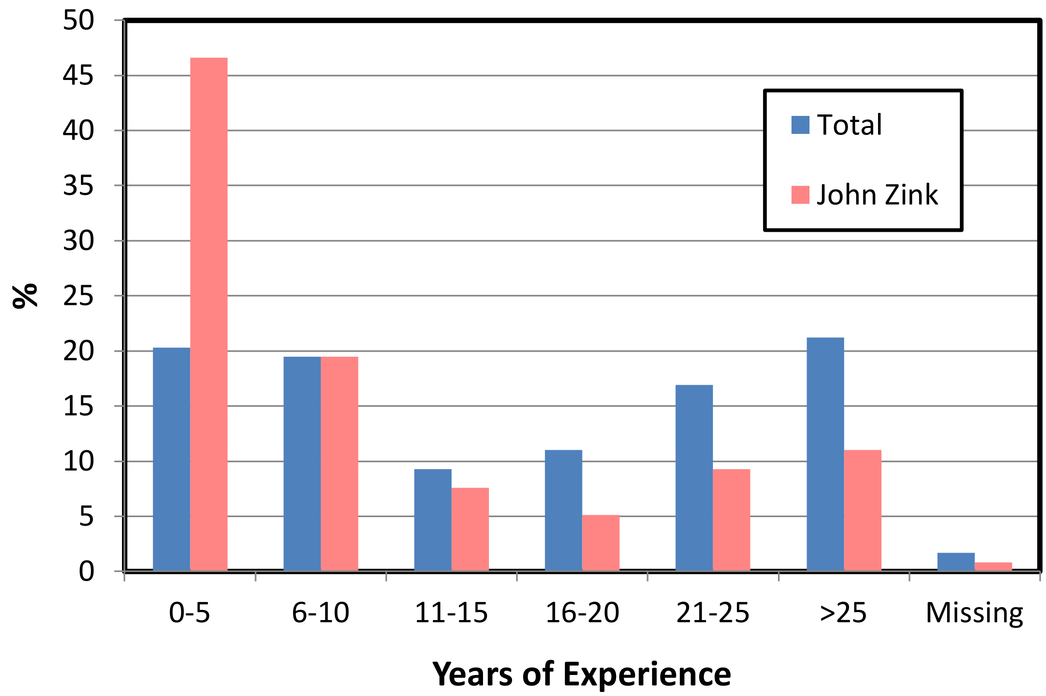


Figure 30. Total years of work experience and years of work experience at John Zink.

As shown in Figure 31 (data from Table H3), most of the participants were individual contributors. The distribution of the management levels in the sample was very similar to the population.

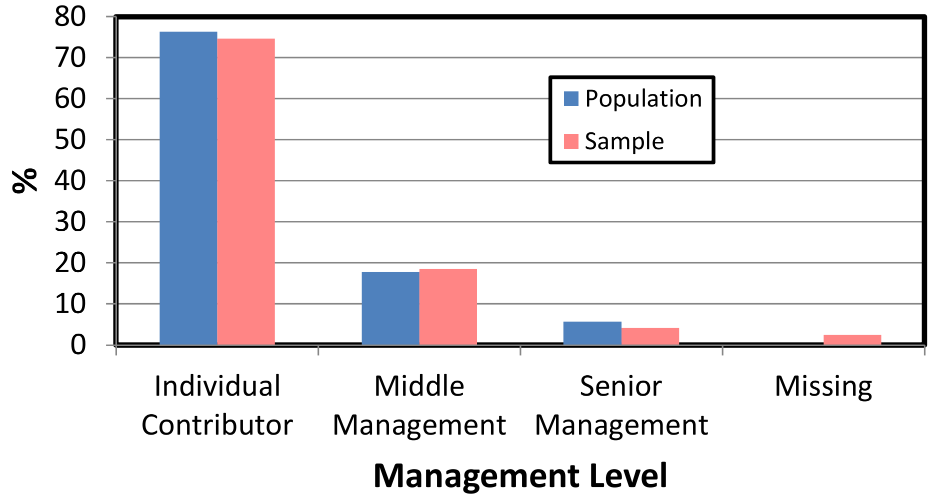


Figure 31. Management level of the participants.

Figure 32 (data from Table H4) shows that about two-thirds of the participants had a Bachelor's degree as their highest engineering degree and 21.2% had some type of engineering graduate degree. Some of the other degrees included: one in business, three high school, one technical college, one non-engineering bachelors, one associates, and one M.S. in chemistry.

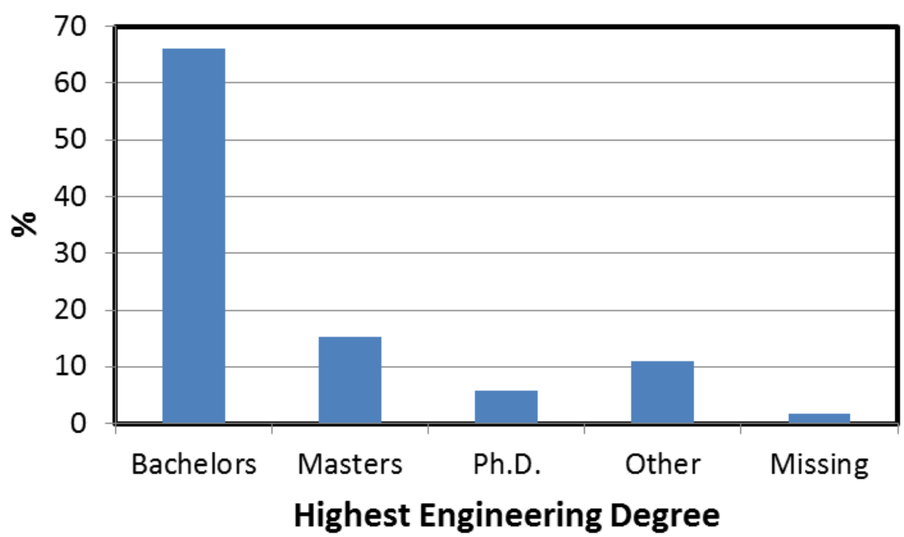


Figure 32. Highest engineering degree of the participants.

As shown in Figure 33 (from the data in Table H5), most of the participants were mechanical engineers by education, followed by chemical engineers and then electrical engineers. The other engineering degree specialties included: one in business management, one in business, two in environmental engineering, one in nuclear electricity/mechanical, one in liberal arts, one in biosystems, one in physics, one in building design/construction, and one in chemistry.

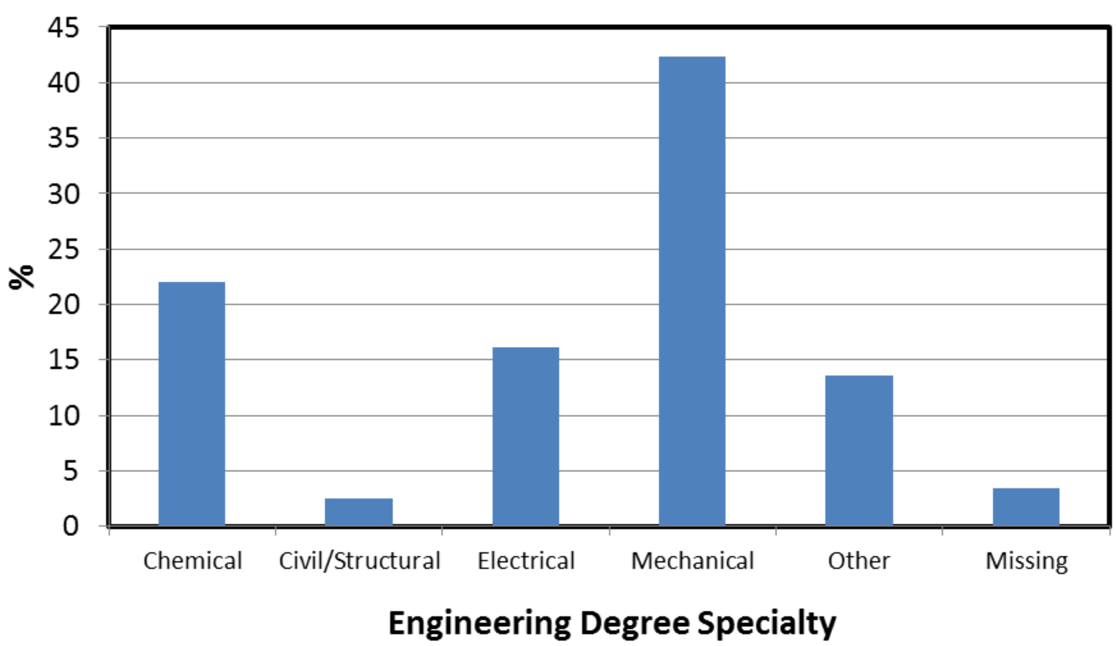


Figure 33. Engineering degree specialty of the participants.

According to Table 10, most of the participants were not licensed professional engineers. No population data were provided by HR on engineering licensure.

Table 10

Professional Engineering license status of the participants.

Professional Engineering License	*N*	Percent
Yes	25	21.2
No	92	78.0
Missing	1	.8
Total	118	100.0

According to Figure 34 (using the data from Table H6), about two-thirds of the participants had little or no prior knowledge of the COOLstar ARIA burner, which was the subject matter used in the study.

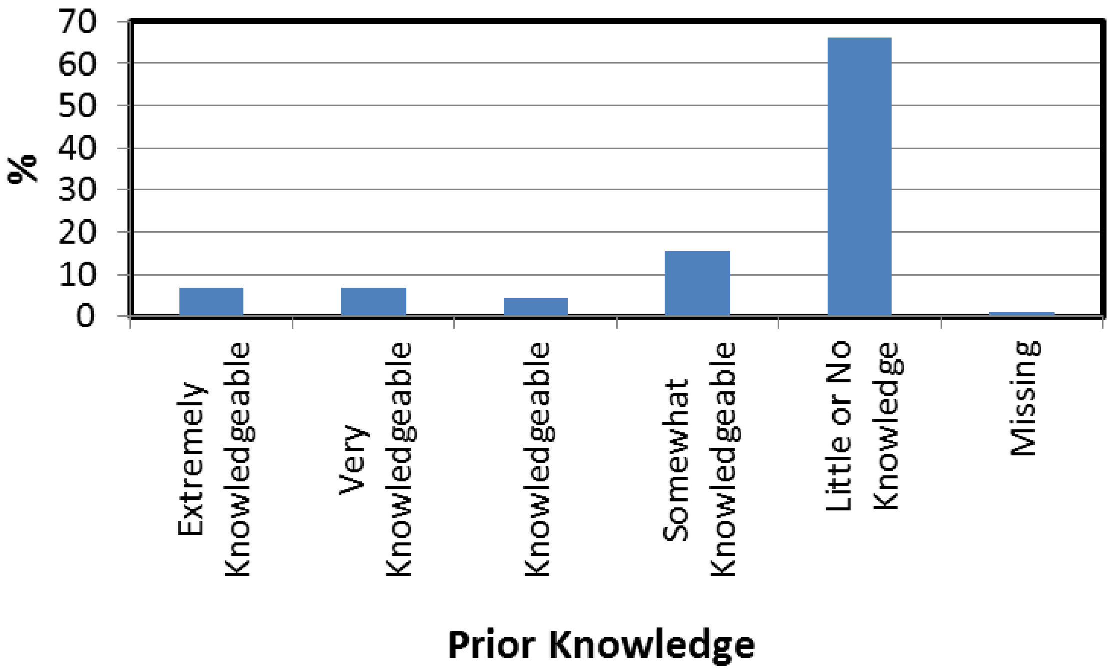


Figure 34. Participants prior knowledge of the COOLstar ARIA burner.

Research Questions

Question #1: What is the learning strategy preference profile for working engineers?

Table 11 shows the overall learning strategy preferences for the participants in this study. Most were Problem Solvers, followed by Navigators, with very few Engagers.

Table 11

Learning strategy preferences of the participants.

	General Population		This Study	
Learning Strategy Preference	*N*	Percent	*N*	Percent
Navigators	43	36.5	30	25.4
Problem Solvers	37	31.7	73	61.9
Engagers	38	31.8	12	10.2
Missing	0	.0	3	2.5
Total	118	100.0	118	100.0

According to Table 12, 83.9% of the participants agreed to at least some degree with their learning strategy preference as determined by ATLAS. Only 11.8% did not agree to some degree with their identified learning strategy preference.

Table 12

Participants' agreement with their learning strategy preference.

Agreement with Learning Strategy Preference	*N*	Percent
Strongly Agree	16	13.6
Moderately Agree	59	50.0
Slightly Agree	24	20.3
Neither Agree Nor Disagree	9	7.6
Slightly Disagree	3	2.5
Moderately Disagree	2	1.7
Strongly Disagree	0	.0
Missing	5	4.2
Total	118	100.0

Question #2: How do the learning strategy preferences of working engineers compare to the norms for the general population?

Figure 35 (data from Table 11) shows the learning strategy preference profile for the participants in this study compared to the general population as reported by Conti (2009). There were nearly double the number of Problem Solvers and less than half the number of Engagers compared to the general population. The ATLAS distribution profile found in this study for working engineers was statistically significantly different than the profile for the general population (χ^2 = 58.149, *df* = 2, *p* = .000), with significantly more Problem Solvers and fewer Engagers.

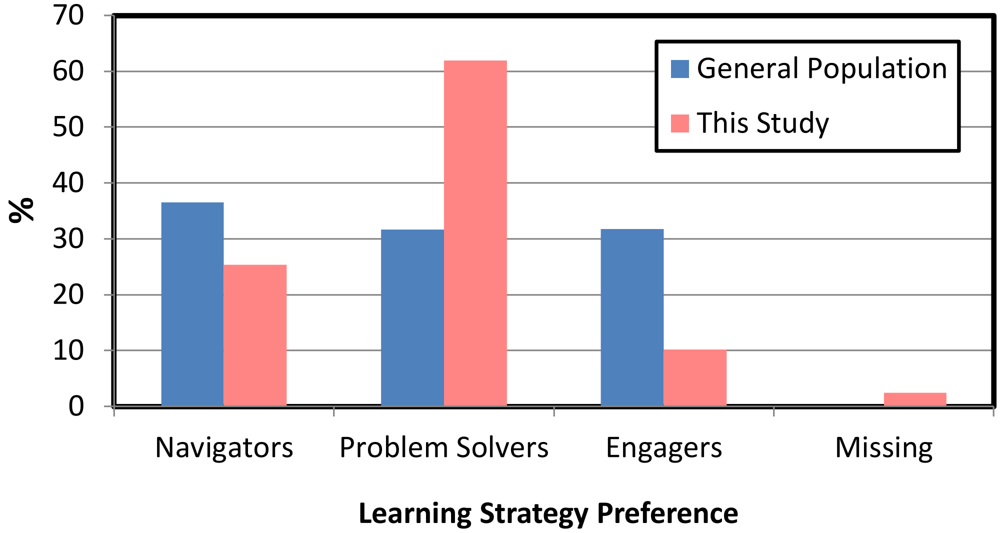


Figure 35. Learning strategy preference profiles of the general population and for the participants in this study.

Question #3: What is the verbal-visual cognitive style profile for working engineers?

Figure 36 (using the data from Table H7) shows the verbal-visual preference profile for the participants in this study. There is a noticeable skew toward the visual cognitive style. The seven categories in the assessment question were reduced to three through consolidation. *Strongly More Verbal than Visual* and *Moderately More Verbal than Visual* were combined to form a new category called *Verbal*. *Slightly More Verbal than Visual*, *Equally Verbal and Visual*, and *Slightly More Visual than Verbal* were combined to form *Neither Verbal nor Visual*. *Moderately More Visual than Verbal* and *Strongly More Visual than Verbal* were combined to form *Visual*. The resulting consolidated verbal-visual preference profile is shown in Figure 37 (data from Table H8). The consolidated results show that most of the participants identified themselves as Visual and very few as Verbal.

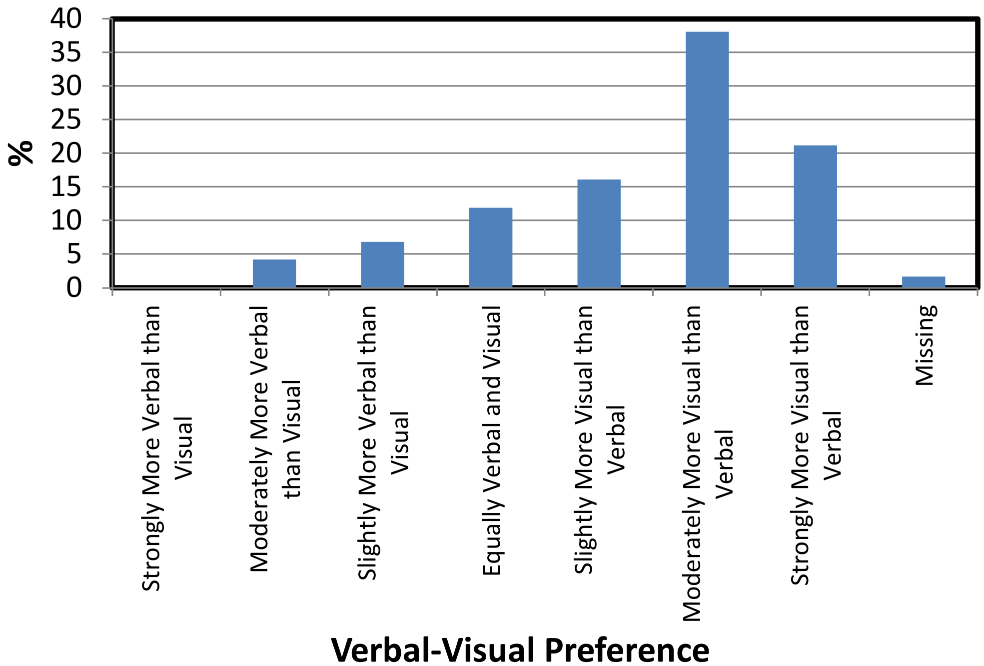


Figure 36. Verbal-visual preference (7 categories) profile for the participants in this study.*

*Note that one participant who selected *Moderately more visual than verbal wrote*, "FYI: more accurately, I learn better from written/printed word and illustration/graphs than I do from anything spoken or narrated."

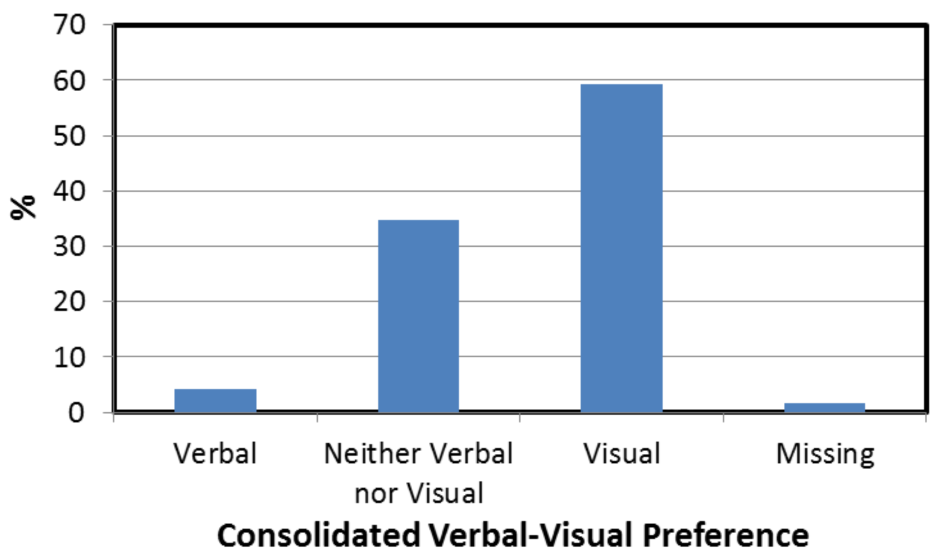


Figure 37. Consolidated verbal-visual preference profile (3 categories) for the participants in this study.

Question #4: How do the verbal-visual cognitive styles of working engineers compare to:

4.1 The norms for the general population?

No consensus was found in the literature for the verbal-visual profile for the general population, which is probably due at least in part to the lack of a single standardized instrument for measuring this profile. In the absence of such a norm, two different recommended profiles were used here for comparison with the sample of working engineers. Richardson (1977) recommended using 15% of the population as habitual verbalizers and 15% as habitual visualizers for research purposes. The 70% balance of the population he recommended considering as bimodal. Leutner and Plass (1998) and Plass (2004) suggested using one-third of the population as verbalizers, one-third as visualizers, and one-third as bimodal. In the present study, individuals indicating they are *Strongly more Verbal than Visual* and *Moderately more Verbal than Visual* were considered verbalizers. Those indicating they are *Strongly more Visual than Verbal* and *Moderately more Visual than Verbal* were considered visualizers. Those indicating they are *Slightly more Verbal than Visual*, *Equally Verbal and Visual*, and *Slightly more Visual than Verbal* were considered bimodal. The cognitive style distribution obtained through this classification strategy was then compared to the expected distributions for general populations predicted by the Richardson and the Leutner and Plass strategies. Figure 38 shows the predicted and measured verbal-visual preference profiles for this study. The measured profile for working engineers was strongly statistically different than the predicted profile for the general population using both Richardson's recommended profile ($\chi^2 = 187.748$, $df = 2$, $p = .000$) and Leutner and Plass' recommended profile ($\chi^2 = 54.845$, $df = 2$, $p = .000$). In the engineering sample, there were more visualizers and fewer verbalizers than these researchers expected in the general population.

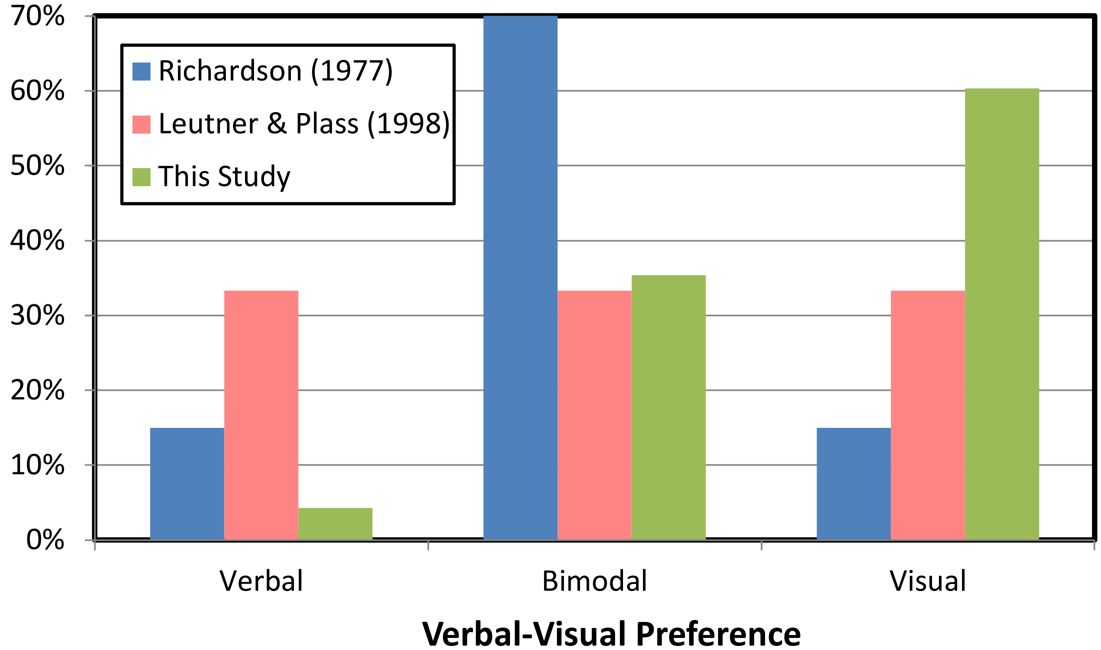


Figure 38. Predicted (from Richardson, 1977 and Leutner & Plass, 1998) verbal-visual preference profiles for the general population compared to the engineering sample for this study.

4.2 The norms for engineers?

No previous measurements of verbal-visual preferences were found for working engineers. However, as discussed in Chapter 2, several studies measured the verbal-visual profiles for engineering students. In the absence of any longitudinal data showing that an engineer's profile changes over time, it was assumed for the purposes of this study that the profiles for working engineers could reasonably be compared to those for engineering students. A potential confounding factor was that it is unknown which of the sampled students in the reported studies graduated and went to work in industry as engineers. In this study's comparison, the constructs for verbal and visual were modified to more closely compare with those used in the previous studies of engineering students where students were essentially classified as either verbal or visual, where only Montgomery (1995) had a very small category in-between. Rosati (1999) and Kirkham, Farkas, and Lidstrom (2006) only used the categories of verbal or visual. Thus, the modified classification used in this study's comparison was *Strongly more Verbal than*

Visual, *Moderately more Verbal than Visual*, and *Slightly more Verbal than Visual* were combined to be *Verbal*. *Strongly more Visual than Verbal*, *Moderately more Visual than Verbal*, and *Slightly more Visual than Verbal* were combined to be *Visual*. The category of *Neither Verbal nor Visual* was classified here as *Bimodal*. Figure 39 shows the comparison of the previous studies of verbal-visual profiles for engineering students compared to the distribution profile measured in this study for working engineers. The measured profile was strongly statistically different than the profiles reported by Montgomery (χ^2 = 151.202, df = 2, p = .000), Rosati (χ^2 = 19578.338, df = 2, p = .000), and Kirkham, Farkas and Lidstrom (χ^2 = 19575.498, df = 2, p = .000). Both the engineering students and the working engineers showed preference for the visual style. However, there was a significant bimodal element among the working engineers that was not present among the students.

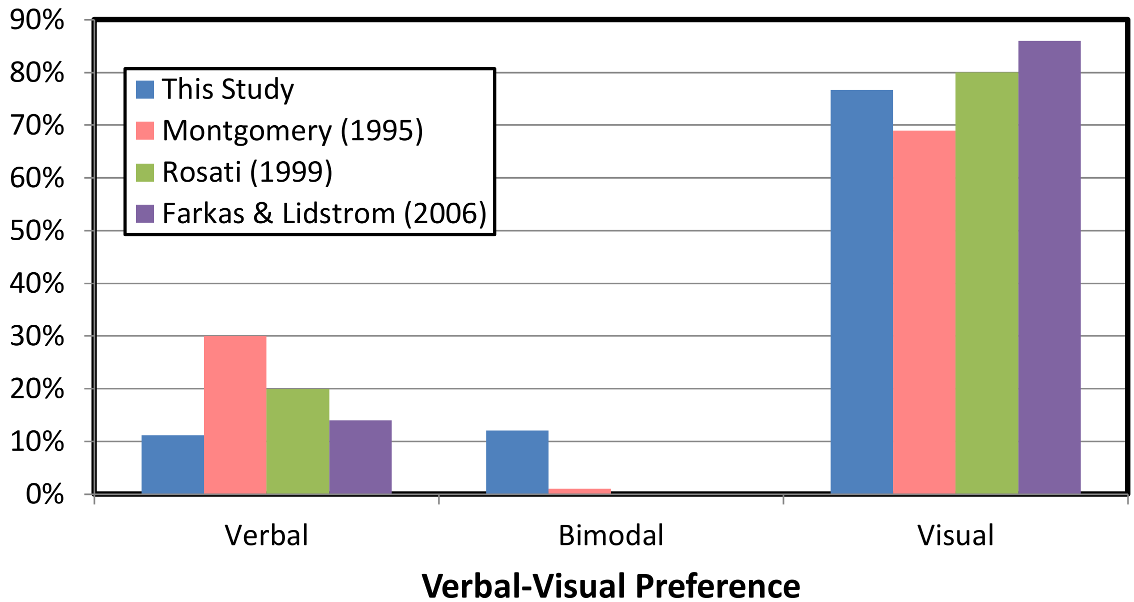


Figure 39. Measured verbal-visual preference profiles for engineering students (Montgomery, 1995; Rosati, 1999; Kirkham, Farkas, & Lidstrom, 2006) compared to the measured profile in this study for working engineers.

Question #5: What are the multimedia preferences of working engineers?

The purpose of Phase 1 of this study was to identify preferences *within a multimedia category*, which addressed sub-questions 5.1 through 5.4 below. The purpose of Phase 2 was to identify preferences *between multimedia categories*, which addressed sub-question 5.5 below. Preference comparisons were made using rating and ranking procedures. The calculation procedures are specified in the Procedures section in Chapter III. Table 13 summarizes the overall ratings and rankings for Phase 1. It also lists the number of discrepancies for each multimedia pair where participants selected different multimedia types in a given pair, depending on the comparison method. For example, they may have chosen one type using rating and the other type using ranking. The discrepancies in Table 13 do not include instances where a participant may have had no preference using one or two of the comparison methods and selected a preferred type with the other method(s).

Table 13

Phase 1 pairwise comparison ratings and rankings.

		#	Rating		Ranking		Relative	
Pair	Multimedia	Discrepancies	*N*	Points	*N*	Points	Rating	Ranking
1	Text	3	86	62.6	86	92	1	1
	Labels + narration		86	23.4	86	166	2	2
2	Drawing	2	86	46.5	85	118	1	1
	Photograph		86	39.5	85	134	2	2
3	Animation	6	86	45.3	85	124	1	1
	Video		86	40.7	85	131	2	2
4	Simulated VR	2	86	46.6	85	121	1	1
	Real VR		86	39.4	85	134	2	2

Table 13 indicates that the working engineers preferred the following multimedia types: text, drawings, animations, and simulated VR.

5.1 What are the verbal preferences of engineers?

Multimedia pair #1 compared two verbal multimedia types: text and labels + narration. Table 14 shows the normalized results of the three methods (preference, rating, and ranking) used to compare these two types. The calculation procedures are given in Chapter III. Text was the strongly preferred verbal medium using all three comparison methods.

Table 14

Comparison of normalized preference, rating, and ranking for the verbal multimedia types.

Comparison Method	*N*	Text	Labels + Narration
Preference	84	1.00	.04
Rating	86	1.00	.37
Ranking	86	1.00	.55
Mean		1.00	.32

5.2 What are the static graphic preferences of engineers?

Multimedia pair #2 compared two static graphic multimedia types: a drawing and a photograph. Table 15 shows the normalized results of the three methods used to compare these two types. Drawing was the moderately preferred static graphic type using all three comparison methods.

Table 15

Comparison of normalized preference, rating, and ranking for the static graphic multimedia types.

Comparison Method	*N*	Drawing	Photograph
Preference	70	1.00	.46
Rating	86	1.00	.85
Ranking	85	1.00	.88
Mean		1.00	.73

5.3 What are the non-interactive dynamic graphic preferences of engineers?

Multimedia pair #3 compared two non-interactive dynamic graphic multimedia types: an animation and a video. Table 16 shows the normalized results of the three methods used to compare these two types. Animation was the slightly preferred non-interactive dynamic multimedia type using all three comparison methods. One participant wrote of the animation, “CAD model has slight glare” where CAD is computer-aided design.

Table 16

Comparison of normalized preference, rating, and ranking for the non-interactive dynamic graphic multimedia types.

Comparison Method	*N*	Animation	Video
Preference	75	1.00	.81
Rating	86	1.00	.90
Ranking	85	1.00	.95
Mean		1.00	.88

5.4 What are the interactive dynamic graphic preferences of engineers?

Multimedia pair #4 compared two interactive dynamic graphic multimedia types: simulated virtual reality and real virtual reality. Table 17 shows the normalized results of the three methods used to compare these two types. Simulated VR was the moderately preferred interactive dynamic multimedia type using all three comparison methods.

Table 17

Comparison of interactive dynamic graphic multimedia types.

Comparison Method	*N*	Simulated VR	Real VR
Preference	75	1.00	.59
Rating	86	1.00	.85
Ranking	85	1.00	.90
Mean		1.00	.78

5.5 What are the preferences of engineers between the multimedia types of verbal, static graphics, non-interactive dynamic graphics, and interactive dynamic graphics?

Multimedia pairs 5 through 10 compared the four different multimedia categories to each other in pairwise comparisons using the three methods of preference, rating, and ranking. There was also an overall comparison of all four categories using rating and ranking methods. Table 18 and Figure 40 show the normalized results of the three pairwise and two overall comparison methods for all four types. The drawing and simulated VR types were approximately equally preferred. The animation was only slightly less preferred. The text was not preferred compared to the other three types. These results are similar to results of multimedia preferences for teacher education students who preferred video and animation over text (Moreno & Ortegano-Layne, 2008).

Table 18

Comparison of normalized comparison methods for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types.

Comparison Method	Text	Drawing	Animation	Simulated VR
Pairwise Preference	.03	.95	.84	1.00
Pairwise Rating	.45	1.00	.97	.99
Pairwise Ranking	.67	.98	.92	1.00
Overall Rating	.42	1.00	.89	.96
Overall Ranking	.49	1.00	.81	.95
Mean	.41	.99	.89	.98

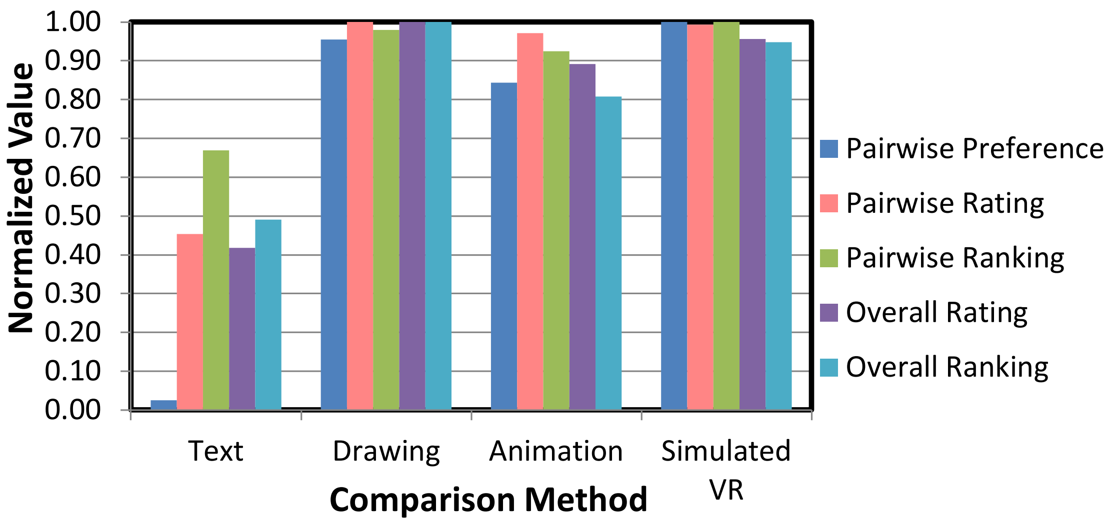


Figure 40. Comparison of normalized comparison methods for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types.

Question #6: What are the relationships of engineers' learning strategy preferences to the demographic variables of gender, age, total engineering work experience, total engineering work experience at John Zink, management level at John Zink, highest engineering degree, specialty for highest engineering degree, professional engineering license, and prior knowledge of the topic?

Figure 41 shows how learning strategy preference varied by gender. The learning strategy preference profiles by gender were statistically significantly different ($\chi^2 = 6.409$, $df = 2$, $p = .041$). There were significantly more Problem Solvers among the male participants compared to Navigators and Engagers. For the female participants, the learning strategy preference profile was much more uniform and closer to that of the profile for the general population.

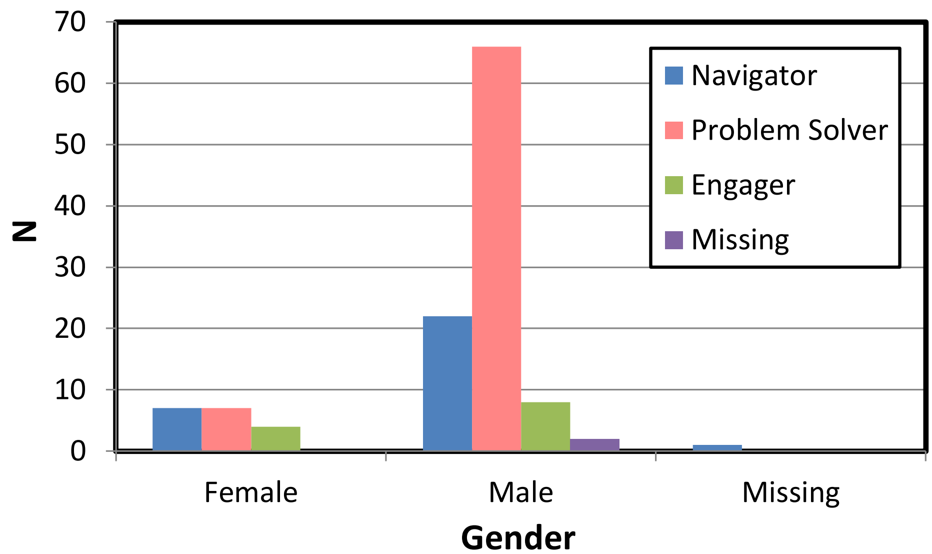


Figure 41. Learning strategy preference vs. gender.

Figure 42 shows how learning strategy preference profile varied with the age of the participants. The profiles by age were not statistically different ($\chi^2 = 12.074$, $df = 10$, $p = .280$). In some age ranges, there were relatively few participants, so Figure 43 shows the profile for wider age ranges. There were no Engagers in the youngest age range (< 36 years old). The profiles for three age ranges approached but did not quite attain statistical significant difference ($\chi^2 = 8.423$, $df = 4$, $p = .077$).

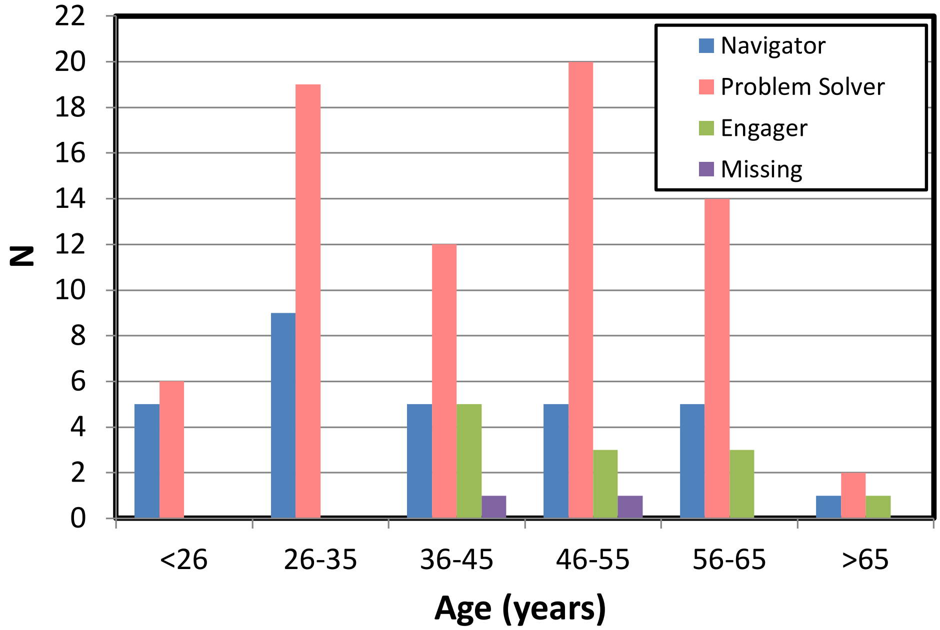


Figure 42. Learning strategy preference vs. age range (6 ranges).

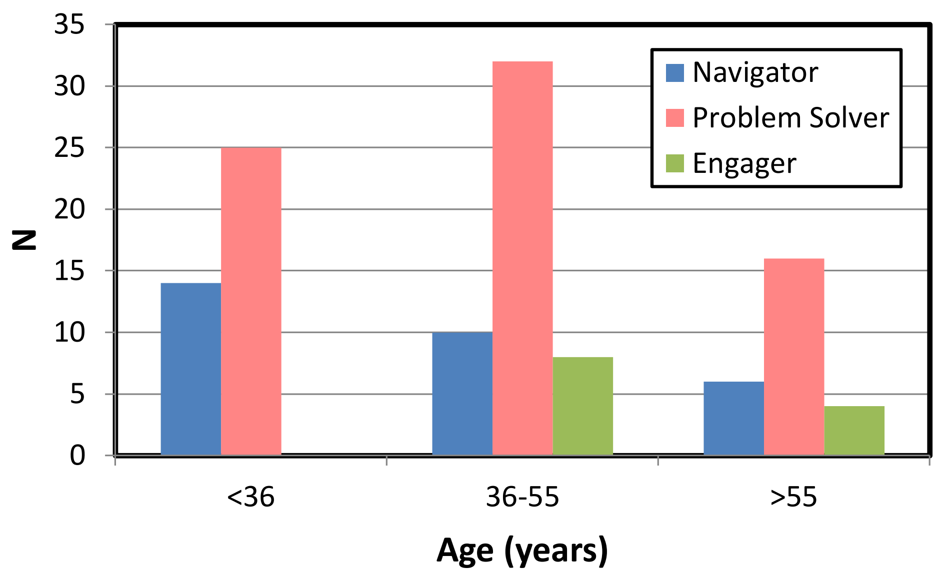


Figure 43. Learning strategy preference vs. age range (3 ranges).

Figure 44 shows learning strategy preference profile as a function of total engineering work experience. The profiles were not statistically different (χ^2 = 7.480, df = 10, p =.680). The work experience ranges were combined in Figure 45 to get more participants in each category as is appropriate for chi-square calculations. The profiles using three work experience categories were not statistically different (χ^2 = 4.175, *df* = 4, *p* = .383).

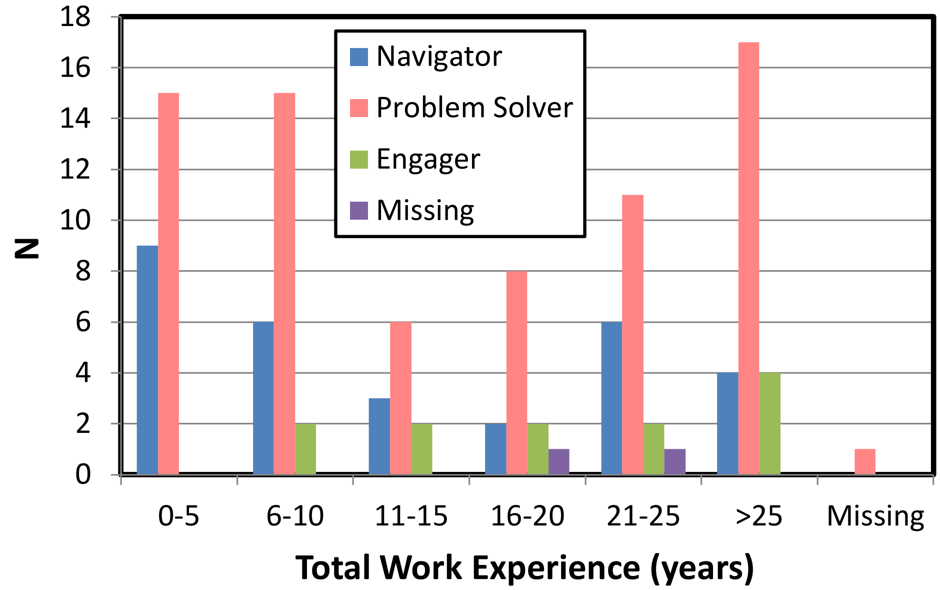


Figure 44. Learning strategy preference vs. total engineering work experience (6 ranges).

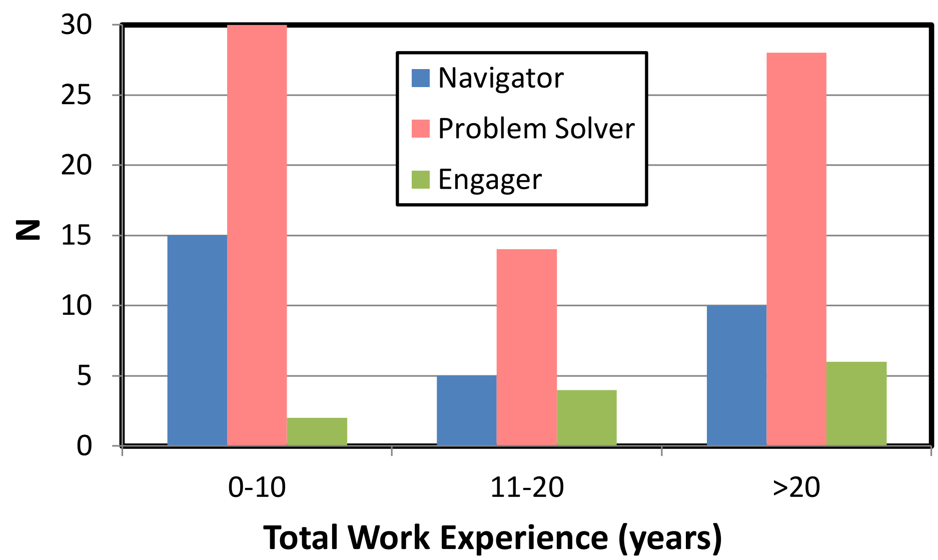


Figure 45. Learning strategy preference vs. total engineering work experience (3 ranges).

Figure 46 shows learning strategy preference based on the years of engineering work experience at John Zink. The profiles were not statistically different (χ^2 = 11.336, *df* = 10, *p* =

.332). Again, ranges were combined to have more participants in each as shown in Figure 47. The profiles using the reduced number of experience categories were not statistically different (χ^2 = 6.906, *df* = 4, *p* = .141).

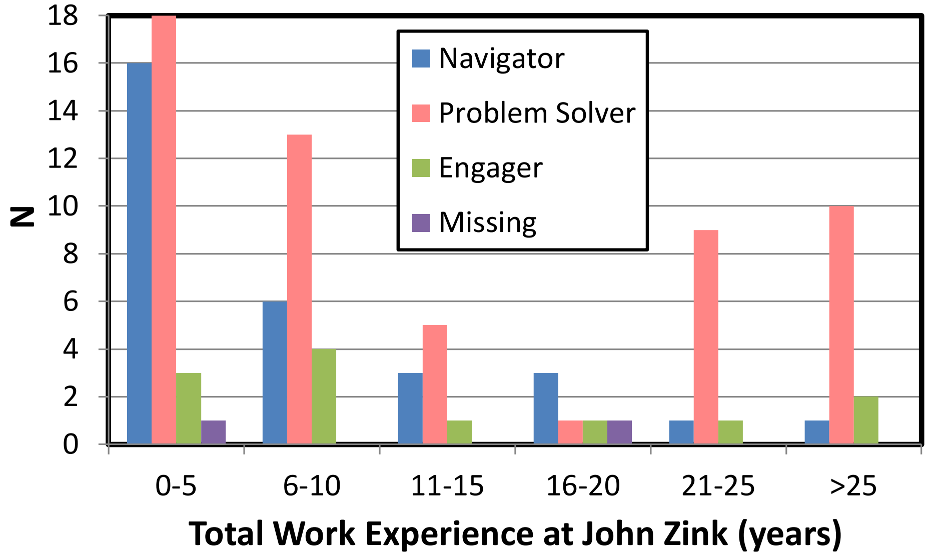


Figure 46. Learning strategy preference vs. total engineering work experience at John Zink (6 ranges).

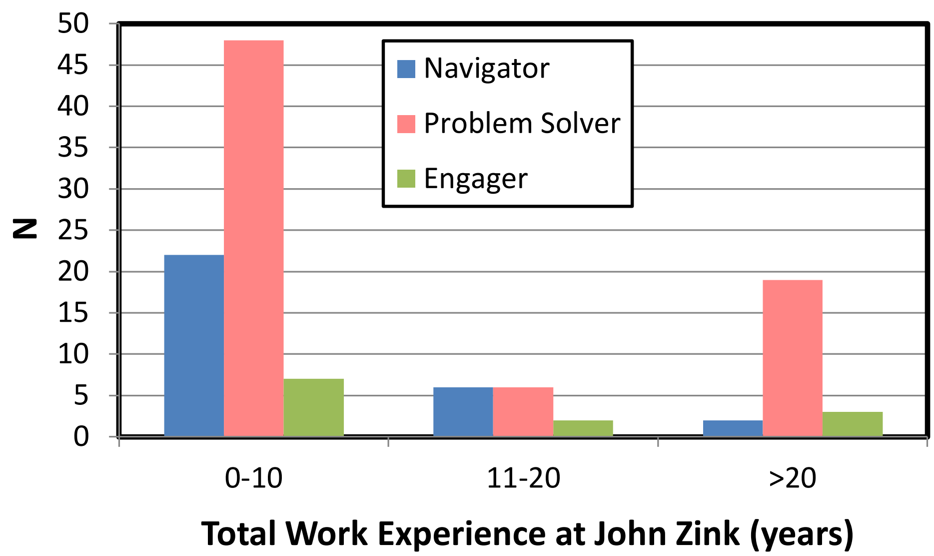


Figure 47. Learning strategy preference vs. total engineering work experience at John Zink (3 ranges).

Figure 48 shows how management level was related to learning strategy preference. The profiles were not statistically different ($\chi^2 = 5.738$, $df = 4$, $p = .220$). Because there were relatively few senior managers in the study, middle and senior managers were combined to form a category called *Manager* as shown in Figure 49. The profiles were not statistically different ($\chi^2 = 4.110$, $df = 2$, $p = .128$).

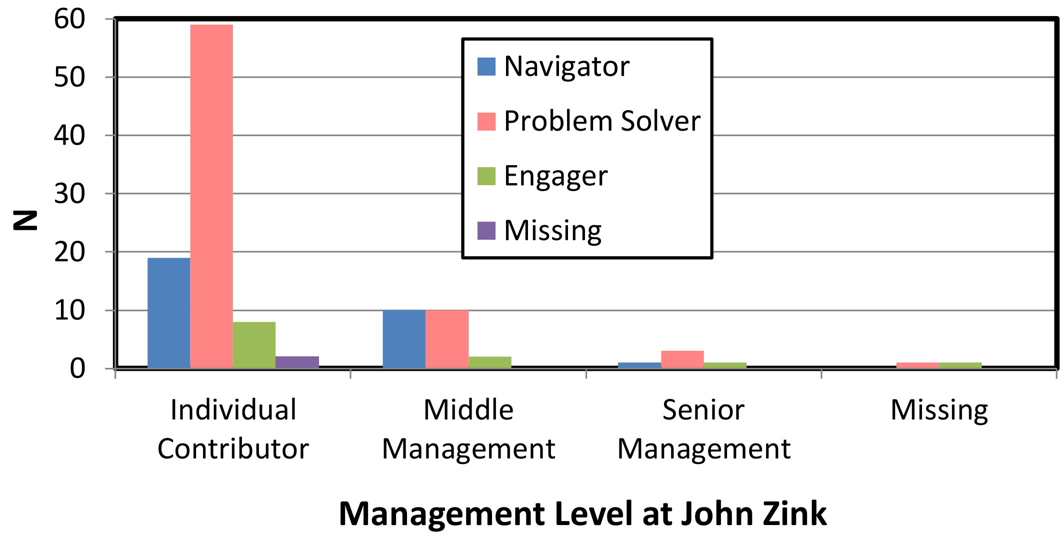


Figure 48. Learning strategy preference vs. management level at John Zink.

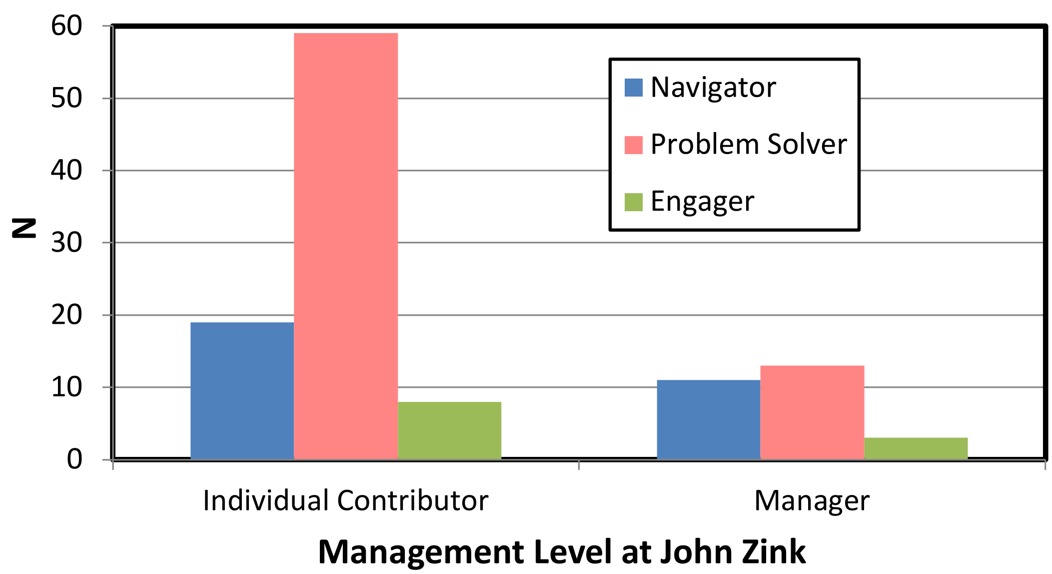


Figure 49. Learning strategy preference vs. management level (individual contributor or manager) at John Zink.

Figure 50 shows learning strategy preference as a function of the highest engineering degree for the participants. The profiles were not statistically different (χ^2 = 10.214, df = 6, p = .116). Because of the relatively small number of Ph.D.s, they were combined with Masters degrees to form a category called *Graduate* as shown in Figure 51. The profiles were not statistically different (χ^2 = 7.313, df = 4, p = .120).

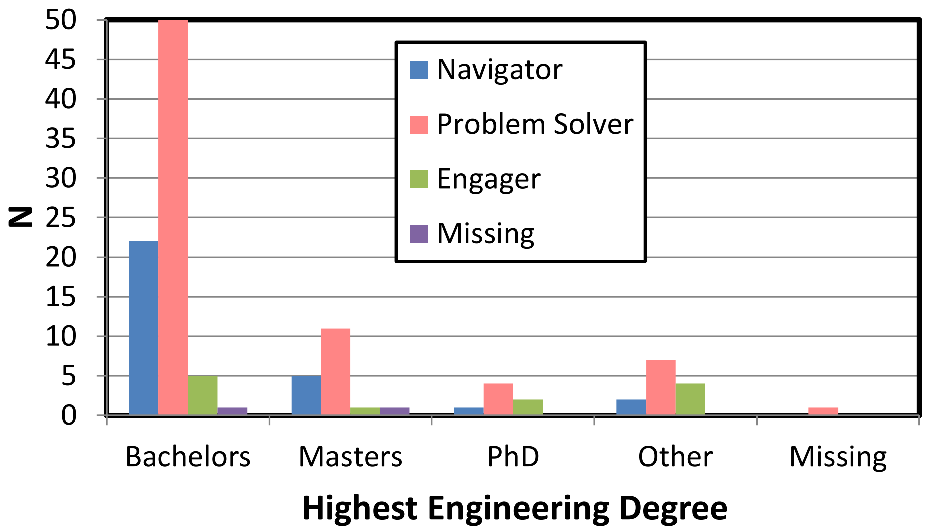


Figure 50. Learning strategy preference vs. highest engineering degree.

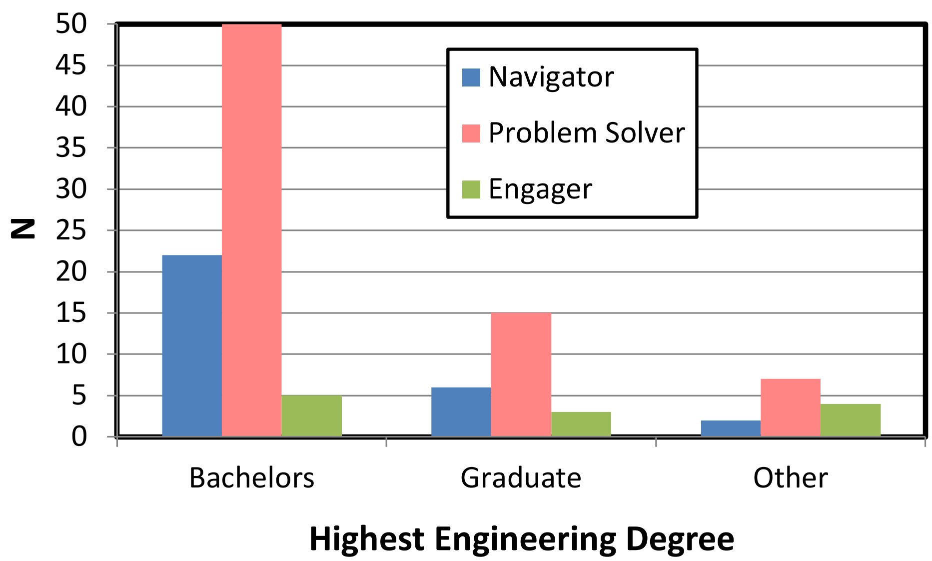


Figure 51. Learning strategy preference vs. highest engineering degree (Masters and Ph.D. combined to form Graduate).

The relationship of engineering specialty for the highest engineering degree of the participants and learning strategy preference is shown in Figure 52. The profiles were not statistically different (χ^2 = 11.810, df = 8, p = .160). Because there were relatively few participants in the specialties of *Civil/Structural*, *Electrical*, and *Other*, they were combined to form a category called *All Others* as shown in Figure 53. The profiles were not statistically different (χ^2 = 3.363, df = 4, p = .499).

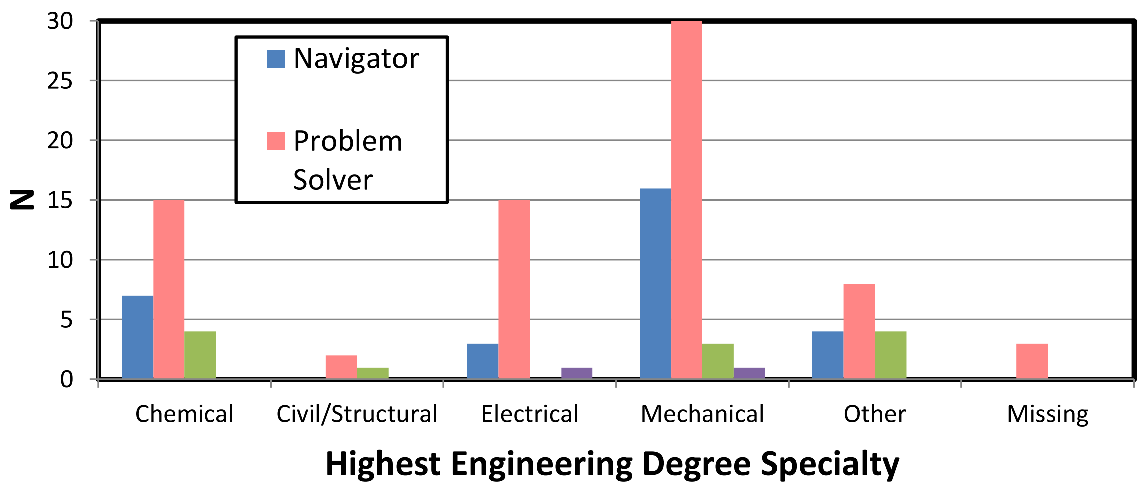


Figure 52. Learning strategy preference vs. specialty for highest engineering degree.

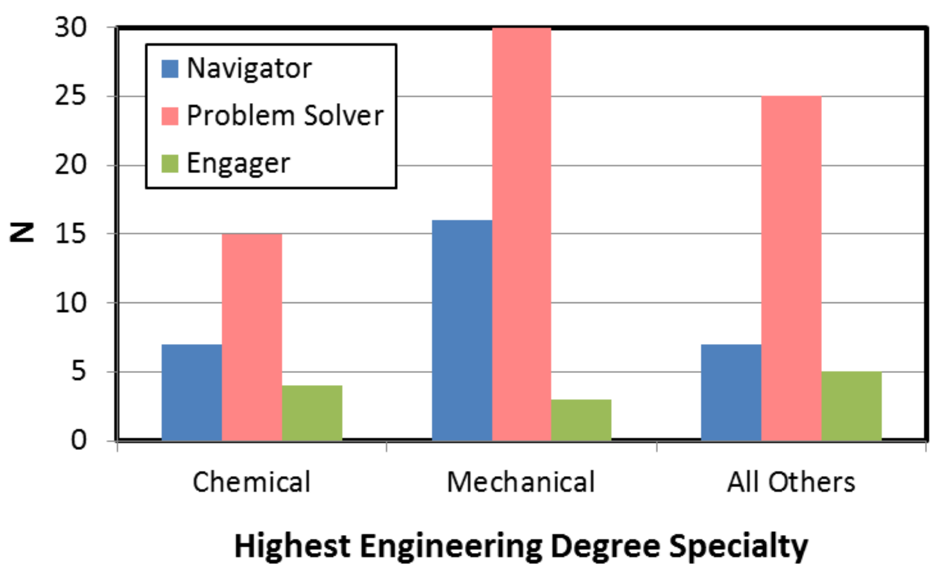


Figure 53. Learning strategy preference vs. specialty (chemical, mechanical, or all others) for highest engineering degree.

Figure 54 shows the relationship of having a Professional Engineering license with participants' learning strategy preference. The profiles were not statistically different (χ^2 =.191, *df* = 2, *p* = .909).

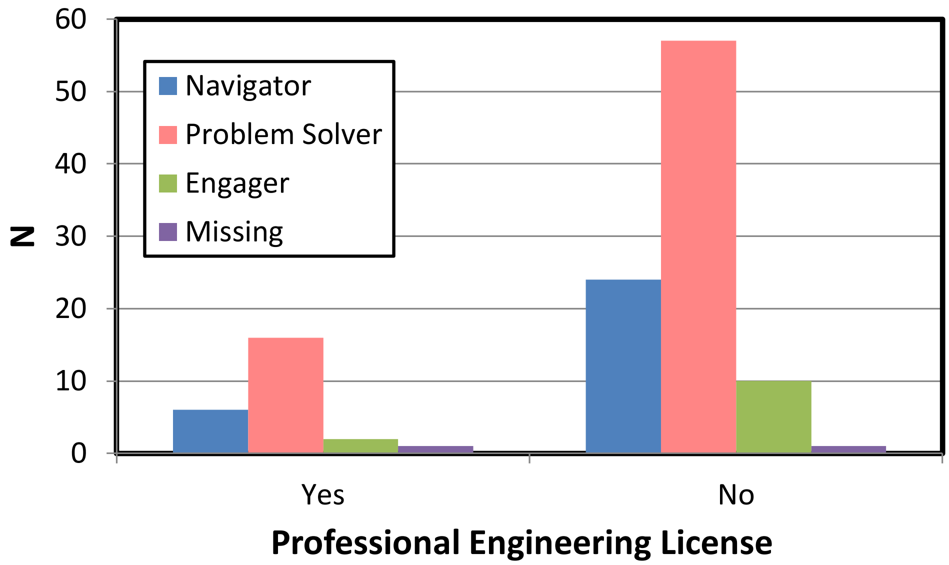


Figure 54. Learning strategy preference vs. professional engineering license.

Figure 55 shows the relationship between prior knowledge of the topic and the learning strategy preference of the participants. The profiles were not statistically different (χ^2 = 8.457, *df* = 8, *p* = .390). Because there were relatively fewer participants in all categories except *Little or no Knowledge*, those categories were combined into a category called *Some Knowledge* as shown in Figure 56. The profiles were not statistically different (χ^2 = 3.223, *df* = 2, *p* = .200).

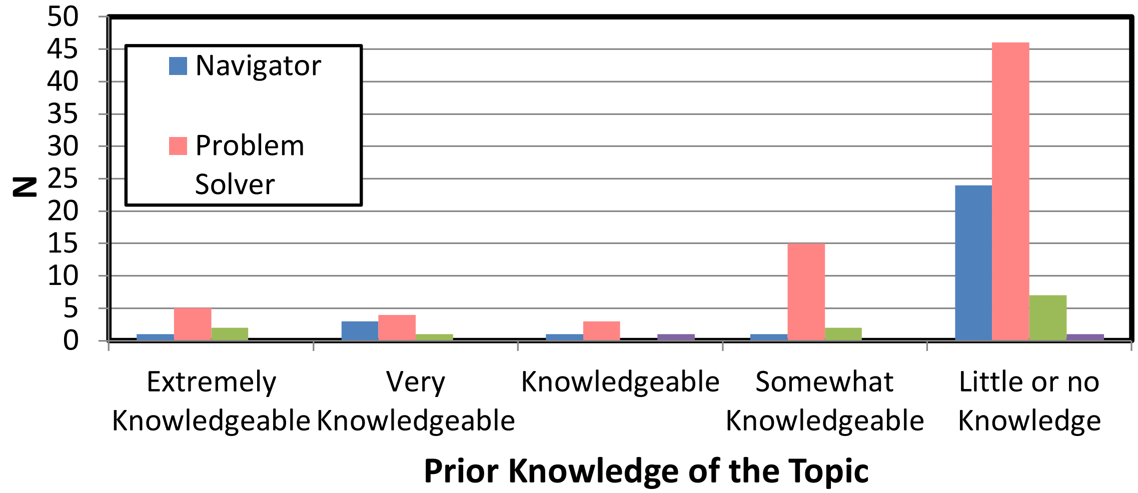


Figure 55. Learning strategy preference vs. prior knowledge of the topic.

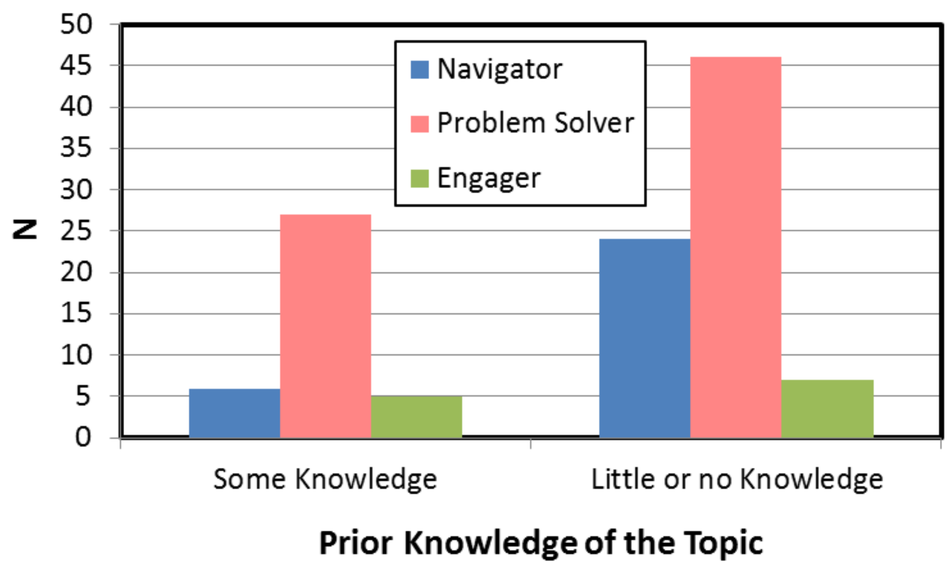


Figure 56. Learning strategy preference vs. prior knowledge (Some Knowledge or Little or no Knowledge) of the topic.

Question #7: What are the relationships of engineers' verbal-visual cognitive styles to the demographic variables of gender, age, total engineering work experience, total engineering work experience at John Zink, management level at John Zink, highest engineering degree, specialty for highest engineering degree, professional engineering license, and prior knowledge of the topic?

Figure 57 shows the relationship between the verbal-visual cognitive style of the participants and their gender. The profiles were not statistically different (χ^2 = 3.631, *df* = 5, *p* = .604). Figure 58 shows the same relationship except with cognitive styles reduced from seven categories to three using the process described previously. None of the female participants fell into the more verbal category. The profiles were not statistically different (χ^2 = 1.118, *df* = 2, *p* = .572).

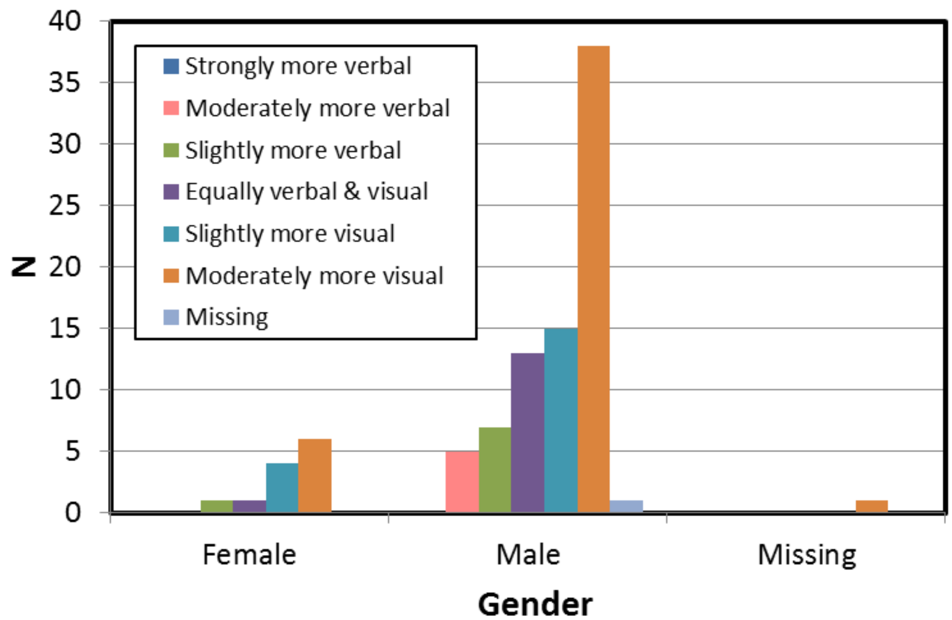


Figure 57. Verbal-visual cognitive style (7 categories) vs. gender.

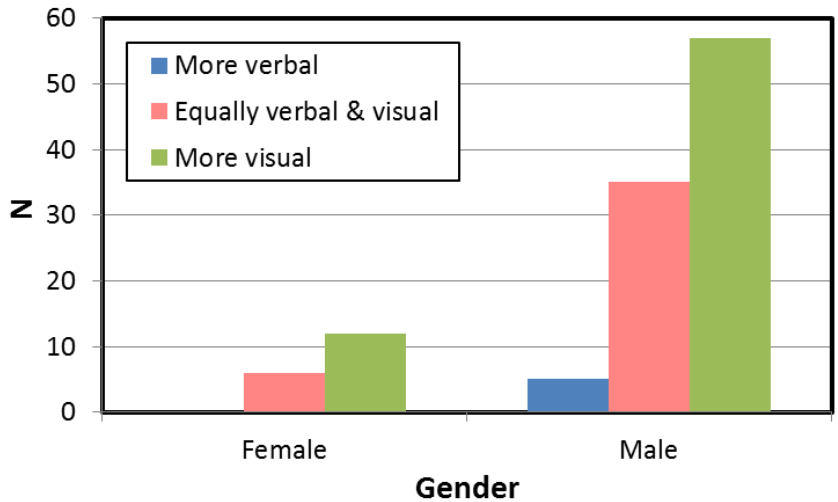


Figure 58. Verbal-visual cognitive style (3 categories) vs. gender.

Figure 59 shows how age was related to participants' verbal-visual cognitive style. The profiles were not statistically different (χ^2 = 34.577, *df* = 25, *p* = .096). Again, style categories were reduced to three as shown in Figure 60. The youngest and oldest categories had no participants in the more verbal category. The profiles were not statistically different (χ^2 = 7.101, *df* = 4, *p* = .131).

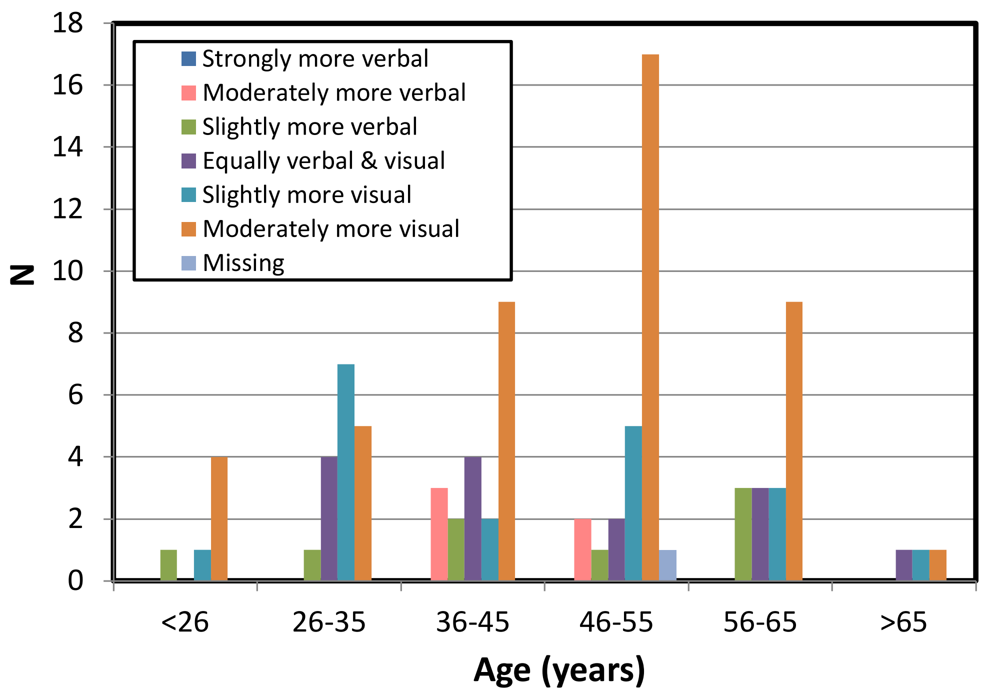


Figure 59. Verbal-visual cognitive style (7 categories) vs. age range (6 ranges).

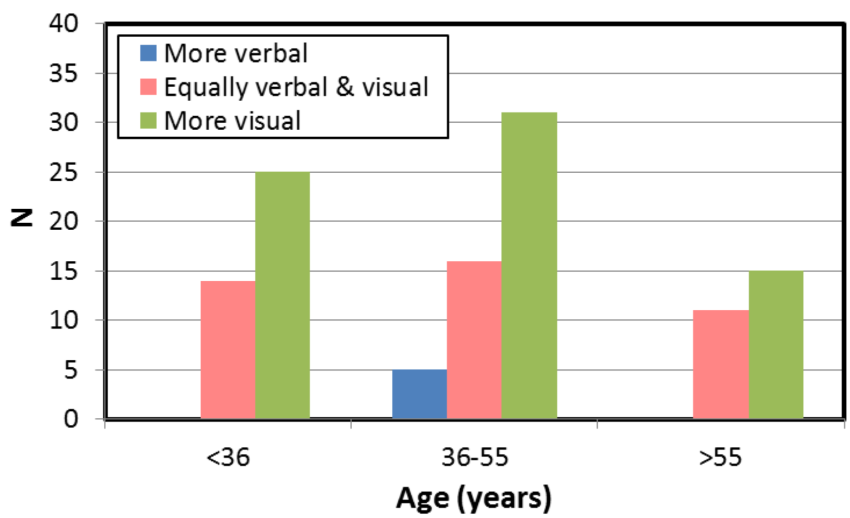


Figure 60. Verbal-visual cognitive style (3 categories) vs. age range (3 ranges).

The relationship between verbal-visual cognitive style and total years of engineering work experience is shown in Figure 61. The profiles were strongly statistically different (χ^2 = 58.790, *df* = 25, *p* = .000). A reduced number of style categories are shown in Figure 62. The profiles were not statistically different (χ^2 = 14.960, *df* = 10, *p* = .134).

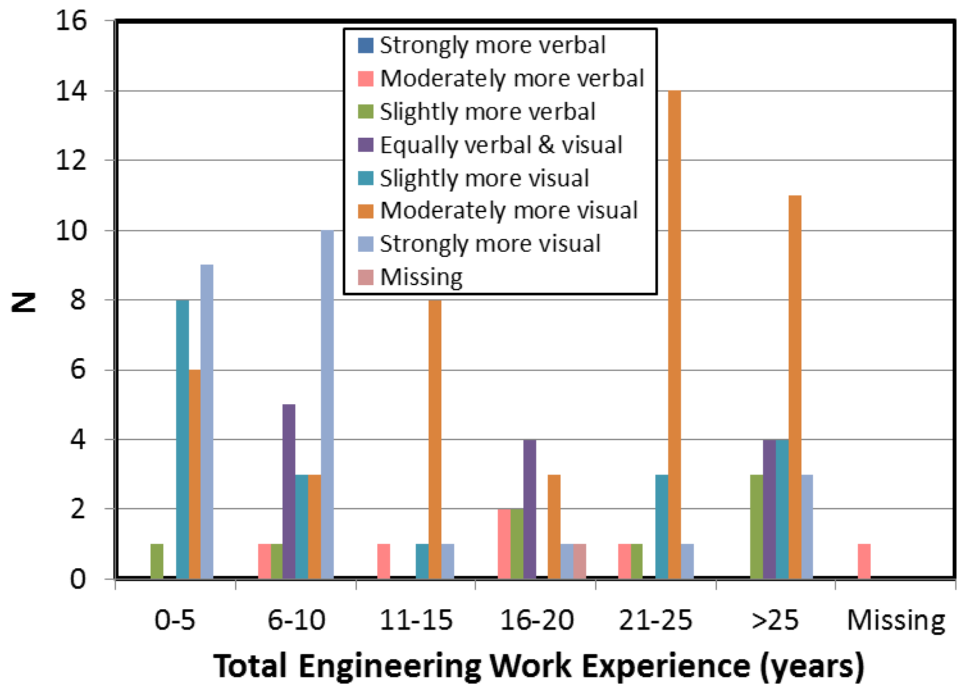


Figure 61. Verbal-visual cognitive style (7 categories) vs. total engineering work experience (6 ranges).

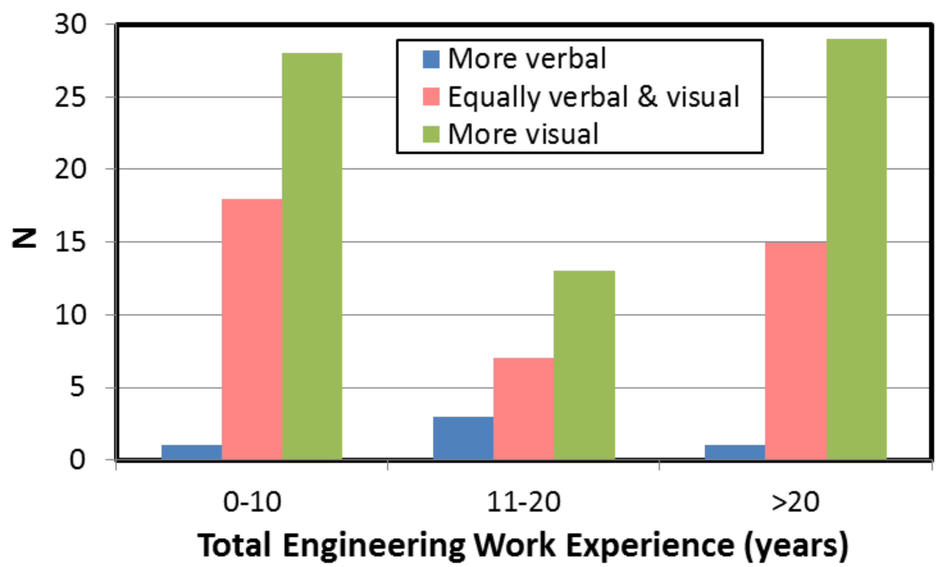


Figure 62. Verbal-visual cognitive style (3 categories) vs. total engineering work experience (3 ranges).

Figure 63 shows how total years of engineering work experience at John Zink was related to participants' verbal-visual cognitive style. The profiles were not statistically different (χ^2 =

17.838, df = 25, p = .849). Figure 64 shows the same data but with cognitive styles reduced to three categories. Those profiles were not statistically different (χ^2 = 1.031, df = 4, p = .905).

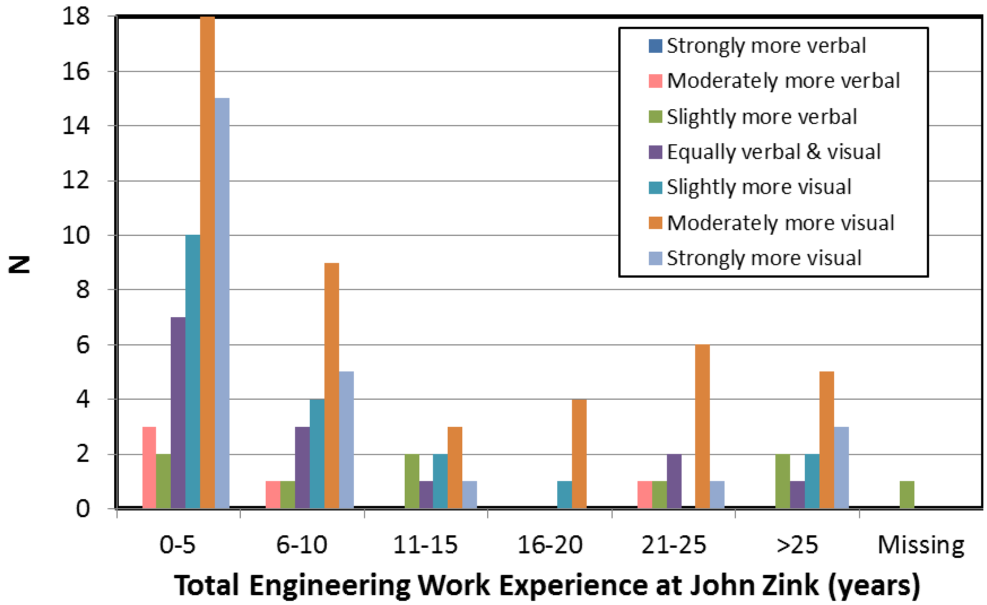


Figure 63. Verbal-visual cognitive style (7 categories) vs. total engineering work experience at John Zink (6 ranges).

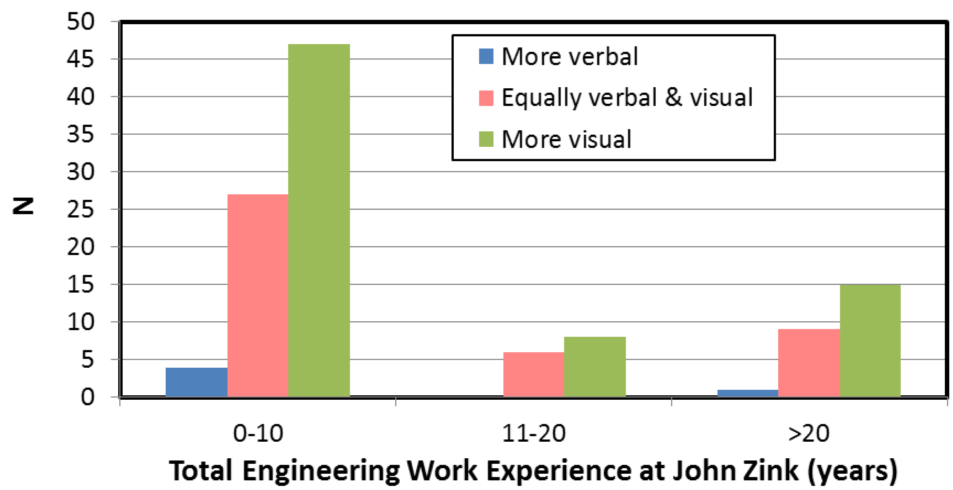


Figure 64. Verbal-visual cognitive style (3 categories) vs. total engineering work experience at John Zink (3 ranges).

The relationship between verbal-visual cognitive style and the management level of the participants is shown in Figure 65. The profiles were not statistically different (χ^2 = 9.908, df =

10, p = .449). Because there were relatively few senior managers, middle and senior managers were combined into a category called *Manager* and the number of style categories was reduced to three as shown in Figure 66. The profiles were not statistically different (χ^2 = 1.912, df = 2, p = .384).

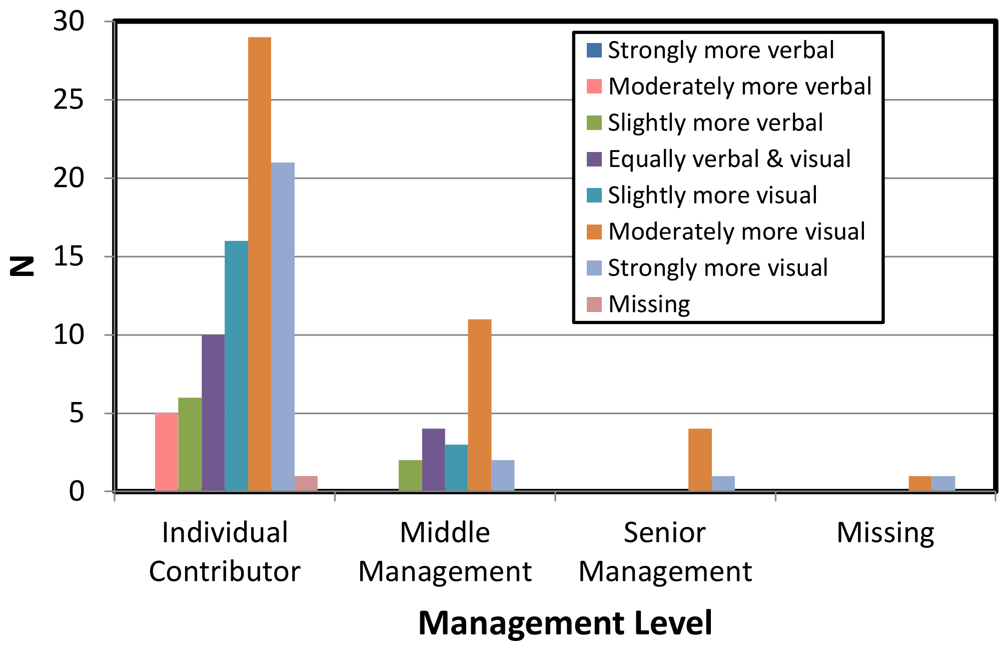


Figure 65. Verbal-visual cognitive style (7 categories) vs. management level at John Zink (3 levels).

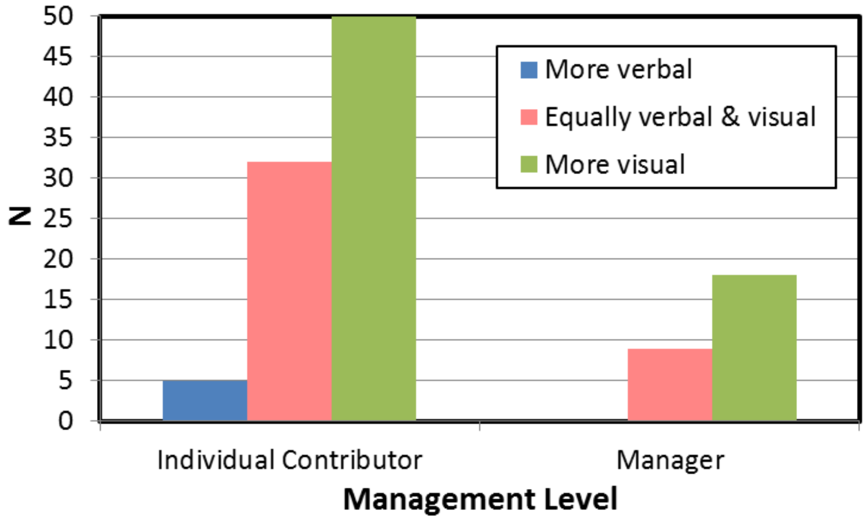


Figure 66. Verbal-visual cognitive style (3 categories) vs. management level at John Zink (2 levels).

The relationship between the highest engineering degree of the participants and their verbal-visual cognitive style is shown in Figure 67. The profiles were not statistically different (χ^2 = 11.365, *df* = 15, *p* = .726). Because there were relatively fewer participants with Masters and Ph.D. degrees, those were combined into *Graduate* degrees and the number of style categories was reduced to three as shown in Figure 68. The profiles were not statistically different (χ^2 = 5.493, *df* = 4, *p* = .240).

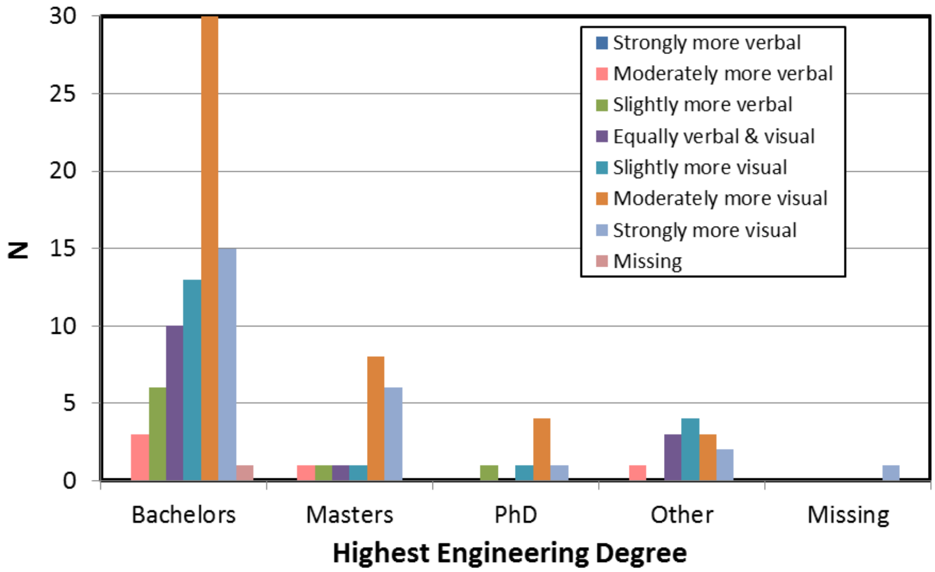


Figure 67. Verbal-visual cognitive style (7 categories) vs. highest engineering degree.

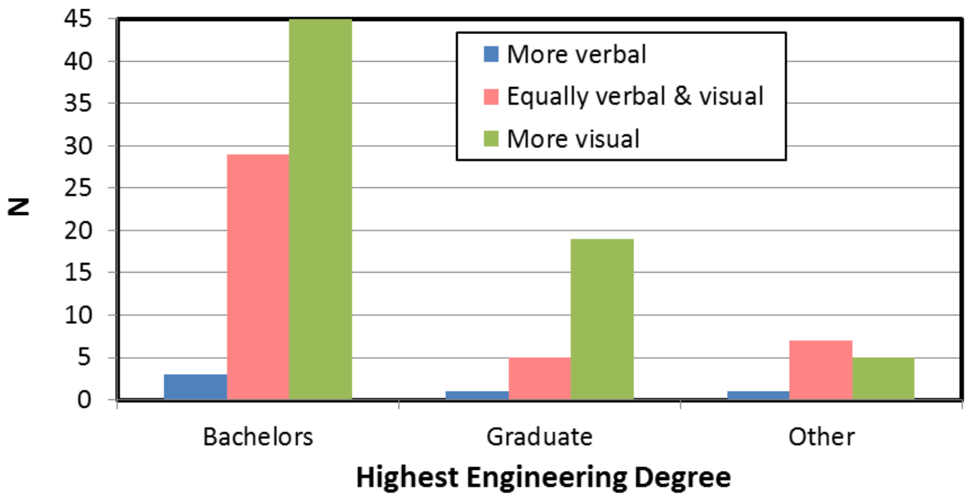


Figure 68. Verbal-visual cognitive style (3 categories) vs. highest engineering degree (Masters + Ph.D. combined).

The relationship between the specialty for the participants' highest engineering degree and their verbal-visual cognitive style is shown in Figure 69. The profiles were not statistically different (χ^2 = 14.238, *df* = 20, *p* = .818). Because of relatively fewer participants, the categories of *Civil/Structural*, *Electrical*, and *Other* were combined into a category called *All Others* and the number of style categories was reduced to three as shown in Figure 70. The profiles were not statistically different (χ^2 = 2.928, *df* = 4, *p* = .570).

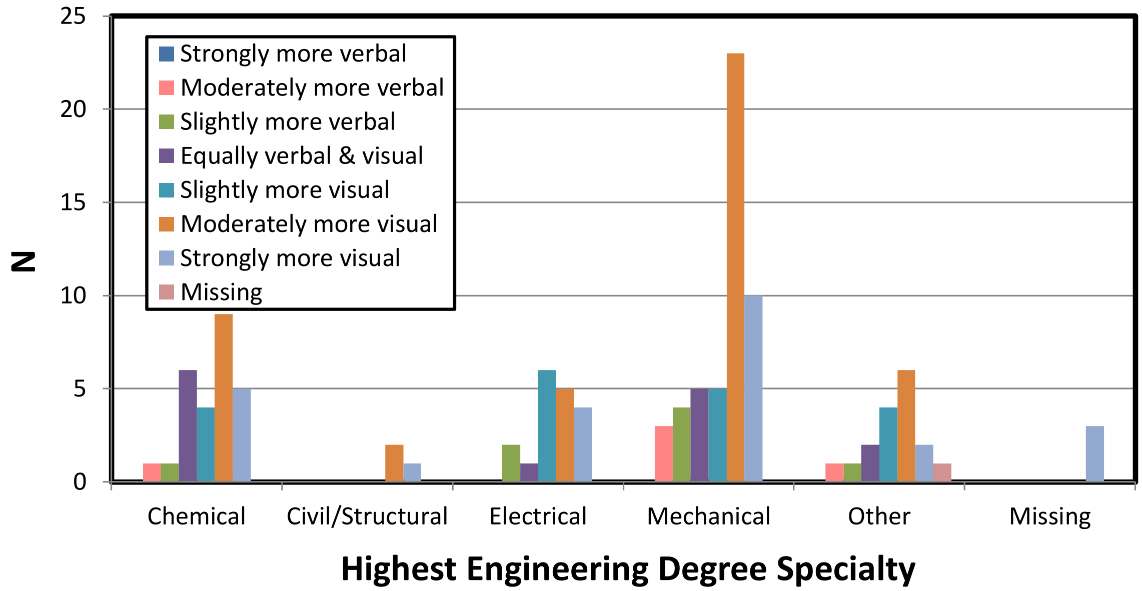


Figure 69. Verbal-visual cognitive style (7 categories) vs. specialty for highest engineering degree.

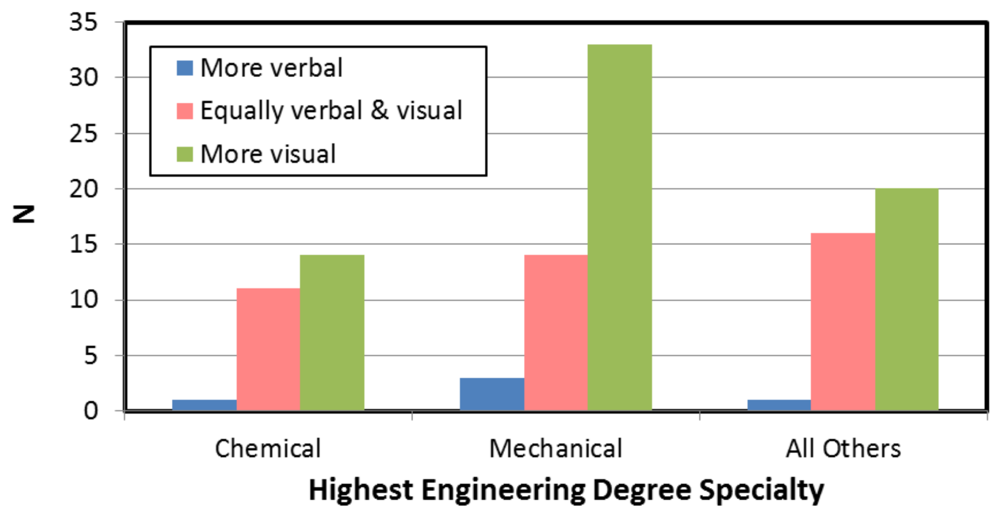


Figure 70. Verbal-visual cognitive style (3 categories) vs. specialty for highest engineering degree (Chemical, Mechanical, and All Others).

The relationship between Professional Engineering licensure status and verbal-visual cognitive style is shown in Figure 71. The profiles were not statistically different (χ^2 = 4.429, *df* =

5, p = .489). The same data but with the style categories reduced to three are shown in Figure 72. The profiles were not statistically different (χ^2 = 1.486, df = 2, p = .476).

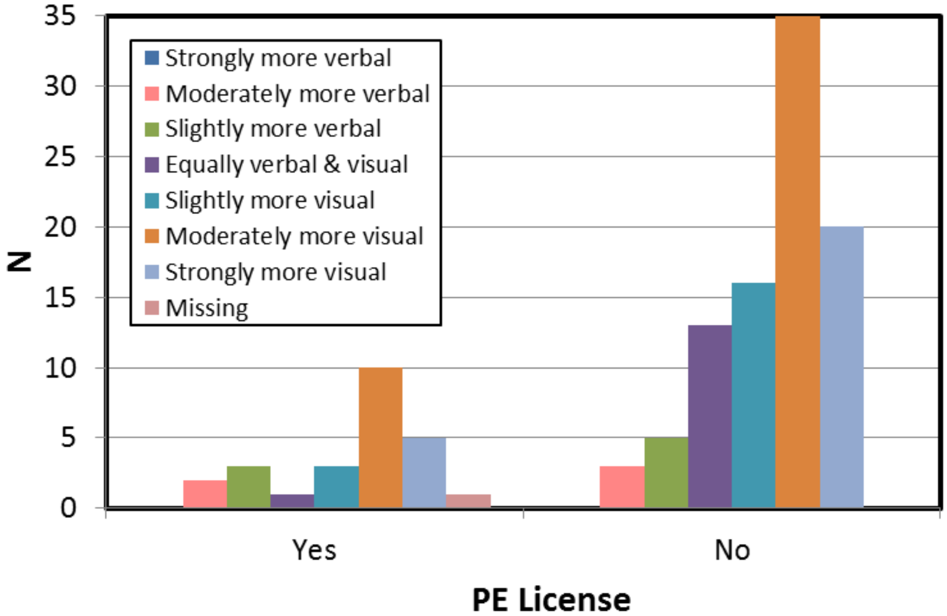


Figure 71. Verbal-visual cognitive style (7 categories) vs. professional engineering license.

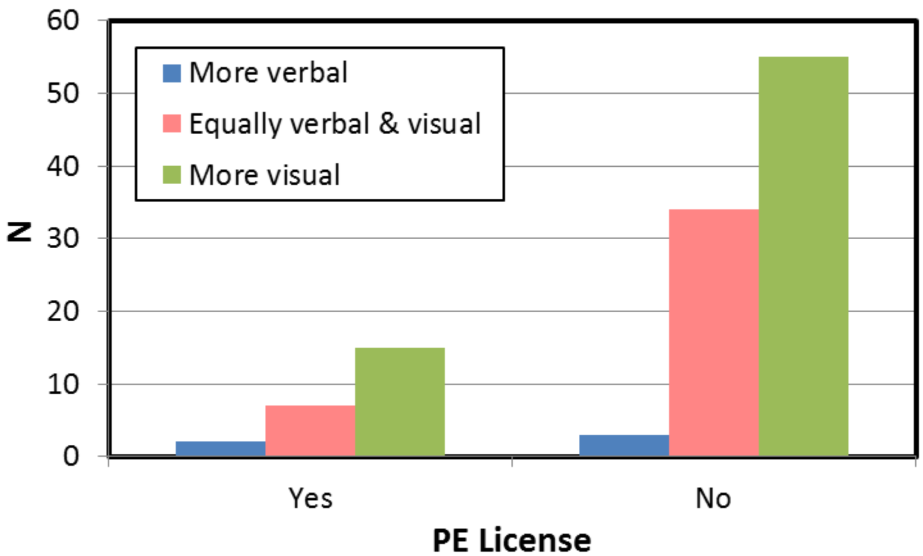


Figure 72. Verbal-visual cognitive style (3 categories) vs. professional engineering license.

Figure 73 shows how participants' verbal-visual cognitive style was related to their prior knowledge of the topic. The profiles were not statistically different ($\chi^2 = 27.918$, $df = 20$, $p = .111$). Figure 74 shows the same data consolidated into three cognitive style categories. Those profiles were not statistically different ($\chi^2 = .174$, $df = 2$, $p = .917$).

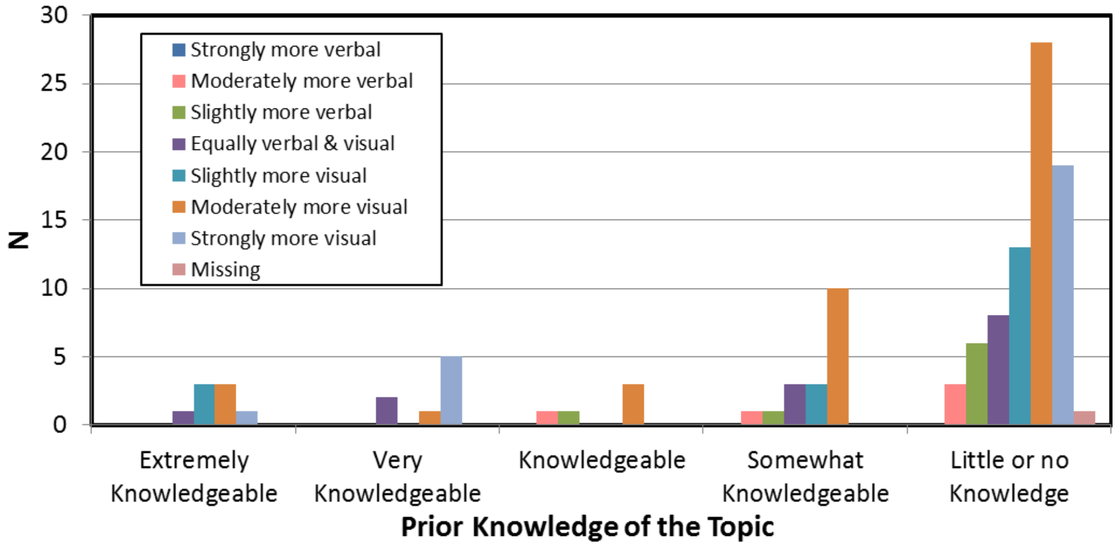


Figure 73. Verbal-visual cognitive style (7 categories) vs. prior knowledge of the topic (5 categories).

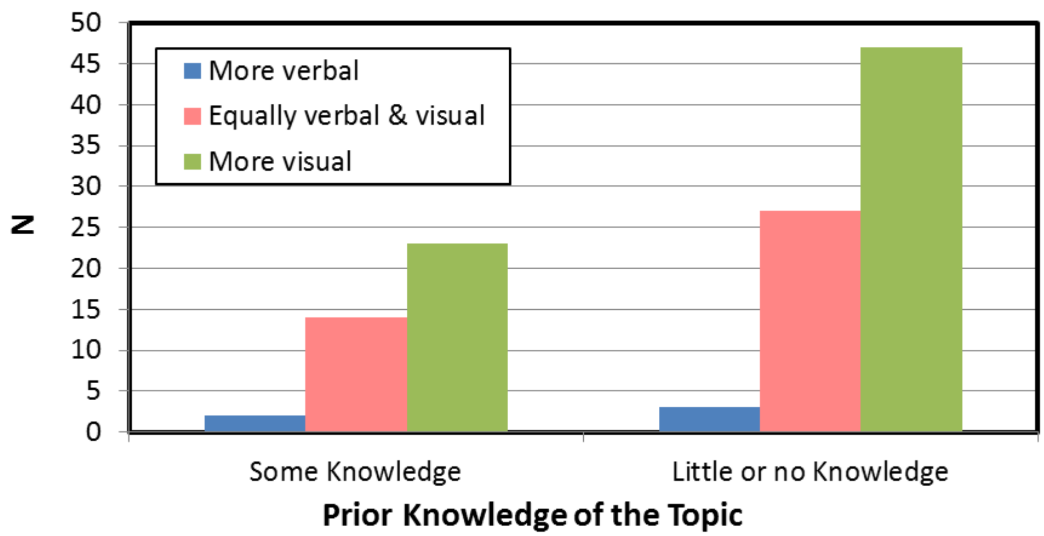


Figure 74. Verbal-visual cognitive style (3 categories) vs. prior knowledge of the topic.

To summarize the relationships of verbal-visual cognitive styles and demographics, there were no statistically significant differences between males and females, different age groups, the three ranges of total work experience, the work experience at John Zink, the management levels, the highest engineering degrees, the specialty of the highest engineering degree, the Professional Engineering licensure status, and prior knowledge of the topic. There was a strong statistically significant difference in verbal-visual cognitive styles and the seven ranges of total engineering work experience.

Question #8: What are the relationships of engineers' multimedia preferences to the demographic variables of gender, age, total engineering work experience, total engineering work experience at John Zink, management level at John Zink, highest engineering degree, specialty for highest engineering degree, professional engineering license, and prior knowledge of the topic?

The answers to this research question are based on participants' multimedia selections in Phase 2 of the study where they selected their preferences among the four categories of verbal, static graphic, non-interactive dynamic graphic, and interactive graphic. The data used here are based on the mean normalized scores of the five methods used to compare the four multimedia categories: (1) preferences in six pairwise comparisons, (2) ratings in six pairwise comparisons, (3) rankings in six pairwise comparisons, (4) ratings in the overall comparison of all four types, and (5) overall ranking of the four types. The results of these five methods were normalized on a scale from zero to one, with one being most preferred and zero being least preferred. The mean of the normalized scores for each of the four types compared in Phase 2 was calculated for each participant. Using mean values allowed for comparison among participants, some of whom did not complete all of the comparisons so averaging compensated for missing data.

Table 19 and Figure 75 show the mean normalized preference score as a function of gender for each of the four multimedia types. The results of an ANOVA analysis as shown in Table 19 indicate there were no statistically significant differences in preferences by gender.

Table 19

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by gender and ANOVA (N = 108, missing = 2, df = 2).

Gender	Text	Drawing	Animation	Simulated VR
Female	.3267	.8056	.7856	.8939
Male	.3528	.8481	.7640	.8189
F	.556	.904	.283	2.376
p	.457	.344	.596	.126

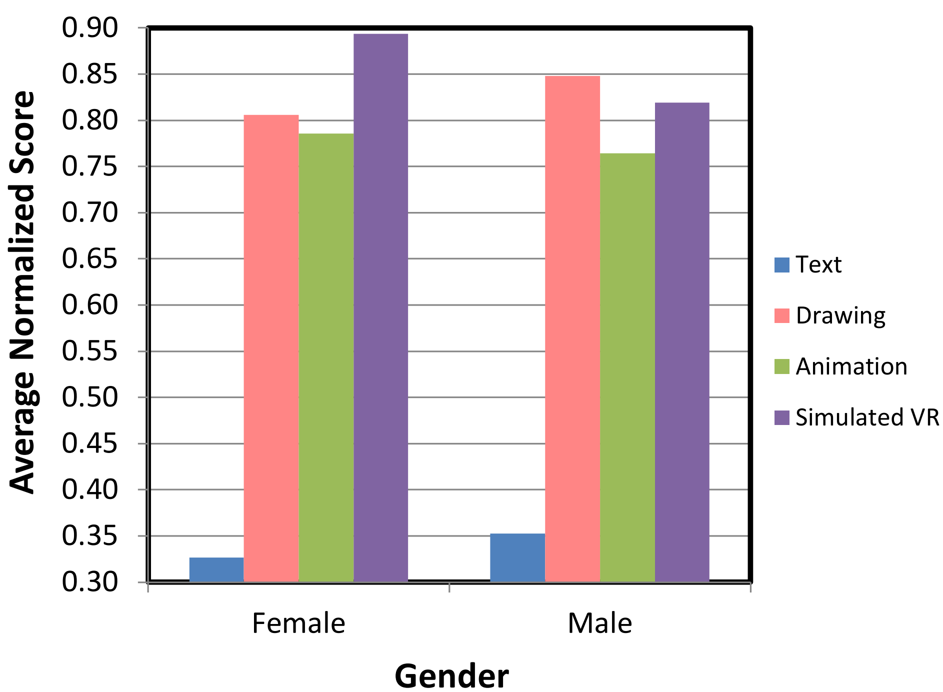


Figure 75. Multimedia preferences vs. gender.

Table 20 and Figure 76 show the mean normalized preference score as a function of the participants' age for each of the four multimedia types. The mean values for the simulated VR by age were statistically significantly different according to an ANOVA.

Table 20

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by age and ANOVA (N = 109, missing = 1, df = 5).

Age (years)	Text	Drawing	Animation	Simulated VR
< 26	.3545	.7582	.8445	.8400
26 – 35	.3764	.8540	.7532	.8680
36 – 45	.3614	.9114	.7648	.7514
46 – 55	.3211	.8254	.7739	.8925
56 – 65	.3130	.8255	.7160	.7650
> 65	.4125	.8450	.8475	.9225
F	.927	1.323	1.249	2.348
p	.467	.260	.292	.046

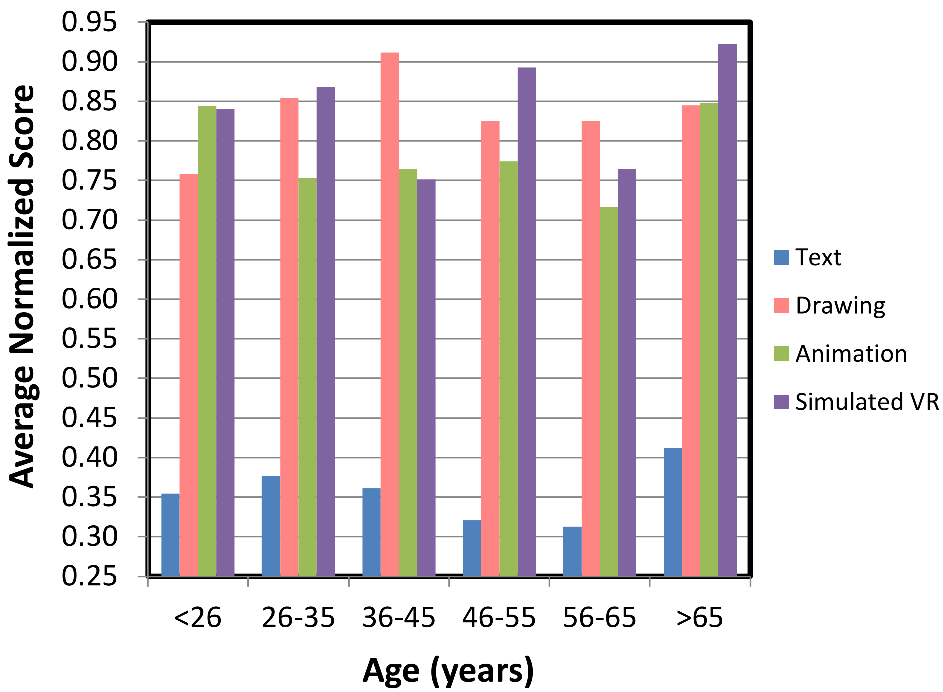


Figure 76. Multimedia preferences vs. age range.

Table 21 and Figure 77 show how participants' multimedia preferences were related to their total engineering work experience. None of the means were statistically significantly different according to an ANOVA.

Table 21

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by total engineering work experience and ANOVA (N = 108, missing = 2, df = 5).

Work Experience (years)	Text	Drawing	Animation	Simulated VR
0 – 5	.3718	.8300	.8355	.8218
6 – 10	.3576	.8162	.7210	.8871
11 – 15	.3573	.8955	.6955	.8127
16 – 20	.3508	.9425	.7900	.7825
21 – 25	.3040	.7990	.7695	.8555
> 25	.3368	.8350	.7550	.7977
F	.599	1.403	1.816	.753
p	.701	.230	.116	.585

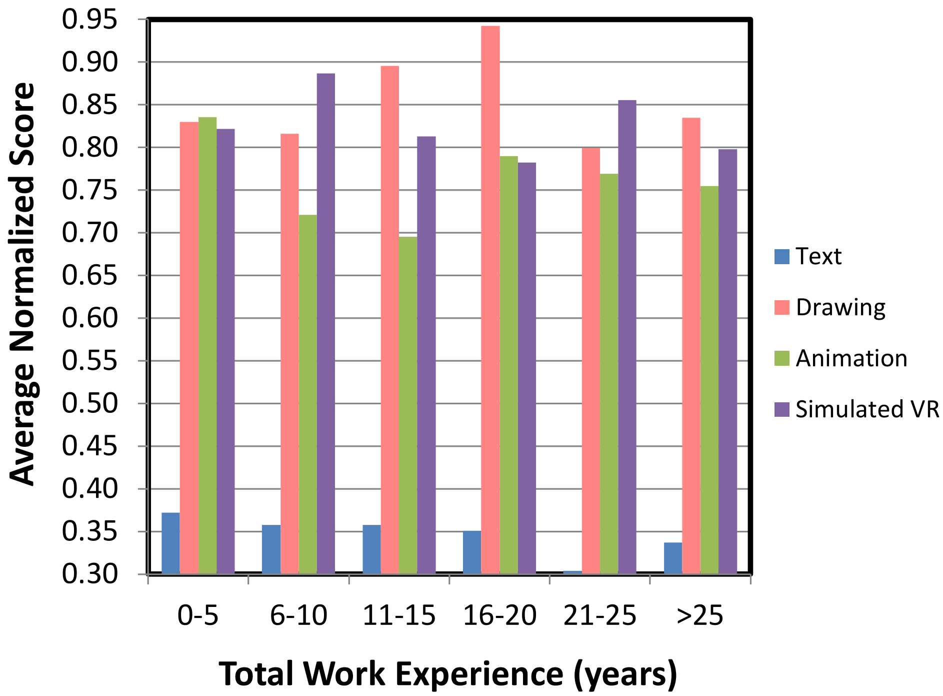


Figure 77. Multimedia preferences vs. total engineering work experience.

Table 22 and Figure 78 show how participants' multimedia preferences were related to their total engineering work experience at John Zink. There were no statistical differences in the means for a given multimedia type as a function of engineering work experience at John Zink.

Table 22

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by total engineering work experience at John Zink and ANOVA (N = 109, missing = 1, df = 5).

JZ Work Experience (years)	Text	Drawing	Animation	Simulated VR
0 – 5	.3685	.8523	.7852	.8575
6 – 10	.3429	.8629	.7248	.7933
11 – 15	.2563	.7812	.7900	.8338
16 – 20	.3200	.8700	.7200	.7233
21 – 25	.2827	.7391	.7945	.8555
> 25	.3964	.8900	.7391	.8209
F	1.885	1.29	.722	.796
p	.103	.274	.608	.555

Figure 78. Multimedia preferences vs. total engineering work experience at John Zink.

The relationships between participants' management level at John Zink and their multimedia preferences are shown in Table 23 and Figure 79. An ANOVA did not show any statistical differences in the means within a multimedia type as a function of management level.

Table 23

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by management level and ANOVA (N = 107, missing = 3, df = 2).

Management Level	Text	Drawing	Animation	Simulated VR
Individual Contributor	.3539	.8361	.7652	.8438
Middle Management	.3055	.8795	.7900	.7905
Senior Management	.4140	.7820	.7220	.8240
F	1.647	.806	.419	.644
p	.198	.449	.659	.527

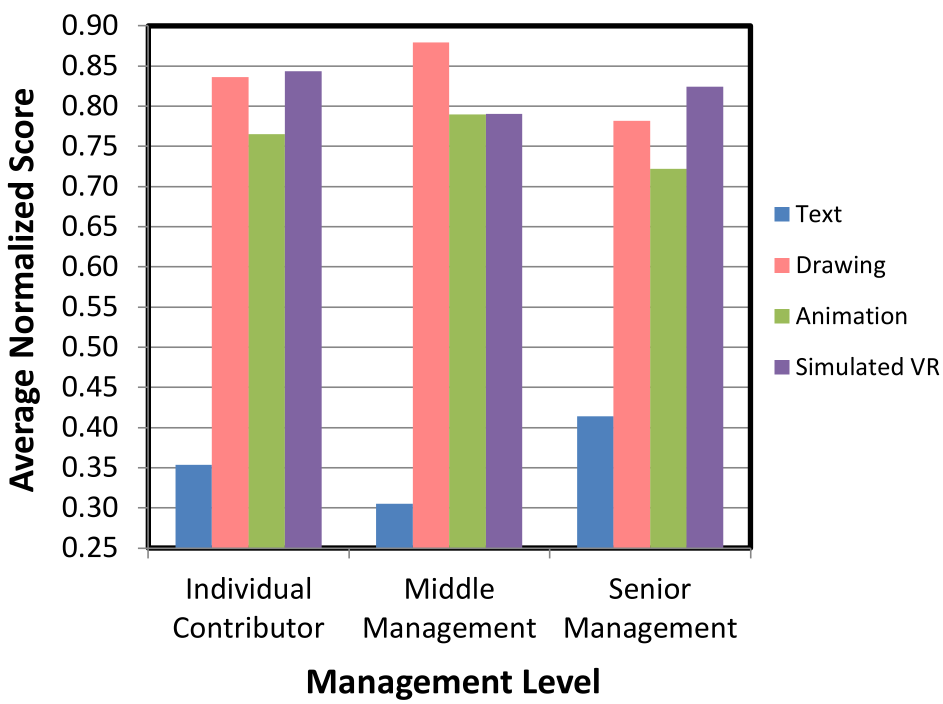


Figure 79. Multimedia preferences vs. management level at John Zink.

The highest engineering degree of the participants' was related to their multimedia preferences as shown in Table 24 and Figure 80. There were no statistically significant differences in the means with each multimedia type as a function of highest engineering degree.

Table 24

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by highest engineering degree and ANOVA (N = 107, missing = 3, df = 2).

Highest Engineering Degree	Text	Drawing	Animation	Simulated VR
Bachelors	.3496	.8366	.7651	.8289
Masters	.3353	.8053	.7729	.8865
Ph.D.	.3971	.9286	.8357	.7700
Other	.3127	.8700	.7236	.8318
F	.590	.954	.735	.723
p	.623	.417	.533	.541

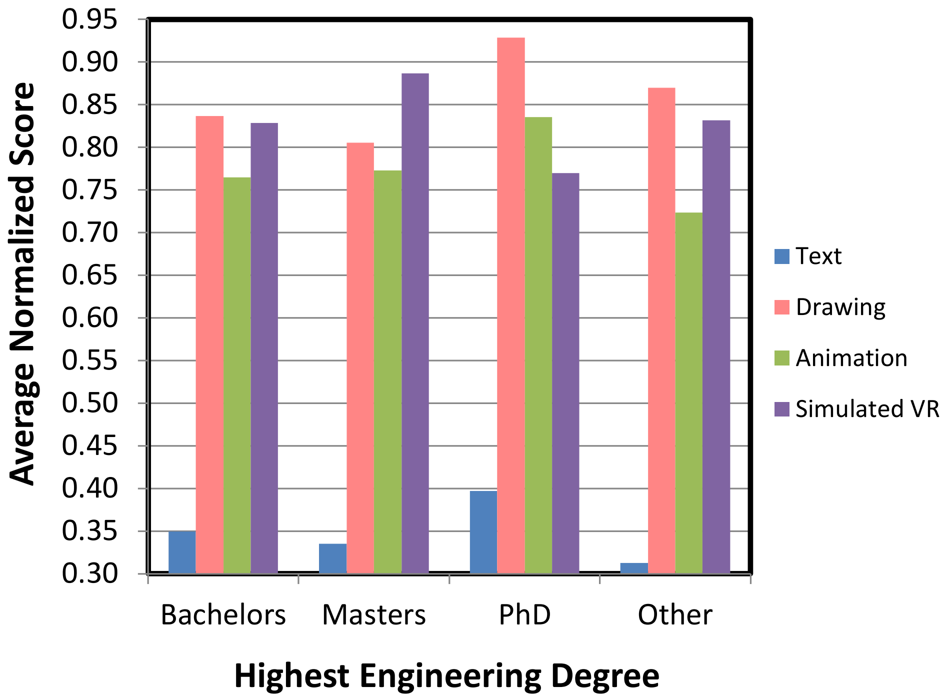


Figure 80. Multimedia preferences vs. highest engineering degree.

Multimedia preferences were related to the specialty of the participants' highest engineering degree specialty as shown in Table 25 and Figure 81. No statistically significant differences in the means were found.

Table 25

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by highest engineering degree specialty and ANOVA (N = 107, missing = 3, df = 4).

Highest Engineering Degree Specialty	Text	Drawing	Animation	Simulated VR
Chemical	.3673	.8585	.8012	.8473
Civil/Structural	.4067	.7800	.7100	.9400
Electrical	.3564	.7921	.6871	.8921
Mechanical	.3447	.8512	.7839	.8092
Other	.3047	.8487	.7307	.8087
F	.659	.476	1.69	.878
p	.622	.753	.158	.480

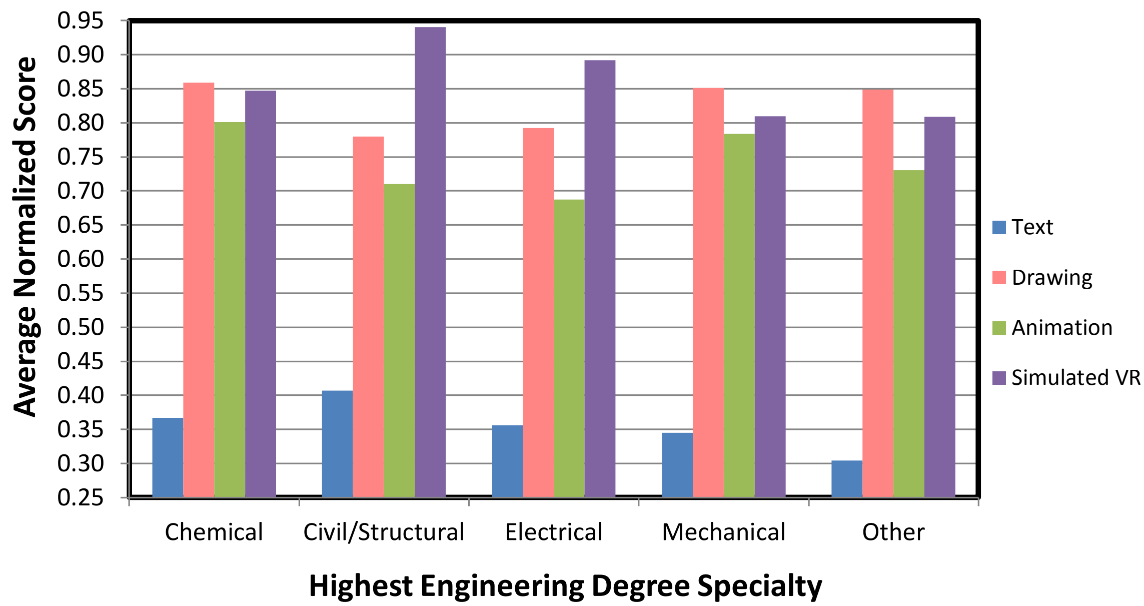


Figure 81. Multimedia preferences vs. specialty for highest engineering degree.

The relationship of participants' Professional Engineering license status on their multimedia preferences is shown in Table 26 and Figure 82. There was a statistically significant difference between those who did and did not have a PE license and their simulated VR preferences.

Table 26

Comparison of mean normalized comparison scores for the verbal, static graphic, non-*interactive dynamic graphic, and interactive dynamic graphic types by professional engineering license status and ANOVA (N = 109, missing = 1, df = 1).*

Professional Engineering License	Text	Drawing	Animation	Simulated VR
Yes	.3625	.8779	.7967	.7475
No	.3424	.8325	.7581	.8560
F	.410	1.293	1.144	6.487
p	.523	.258	.287	.012

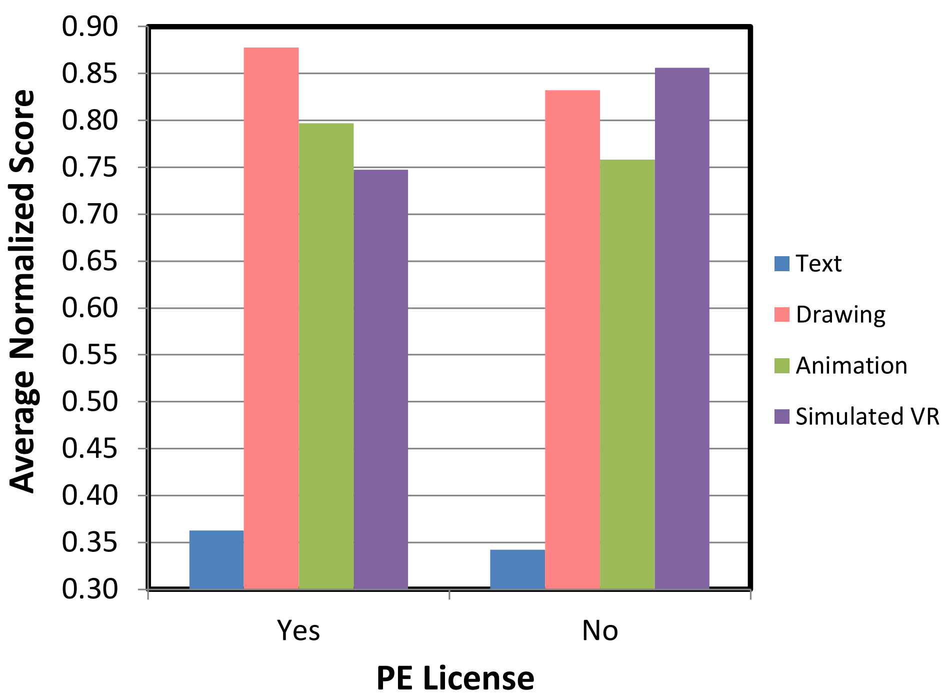


Figure 82. Multimedia preferences vs. professional engineering license.

The relationship between participants' prior knowledge of the topic and their multimedia preferences is shown in Table 27 and Figure 83. No statistically significant differences in the means within a multimedia type were found using an ANOVA.

Table 27

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by prior knowledge and ANOVA (N = 109, missing = 1, df = 4).

Prior Knowledge	Text	Drawing	Animation	Simulated VR
Extremely Knowledgeable	.3063	.8937	.8475	.8750
Very Knowledgeable	.3500	.8457	.7586	.7857
Knowledgeable	.4520	.8880	.8540	.8000
Somewhat Knowledgeable	.3582	.8065	.7818	.8847
Little or No Knowledge	.3410	.8418	.7487	.8217
F	.993	.437	1.220	.620
p	.415	.781	.307	.649

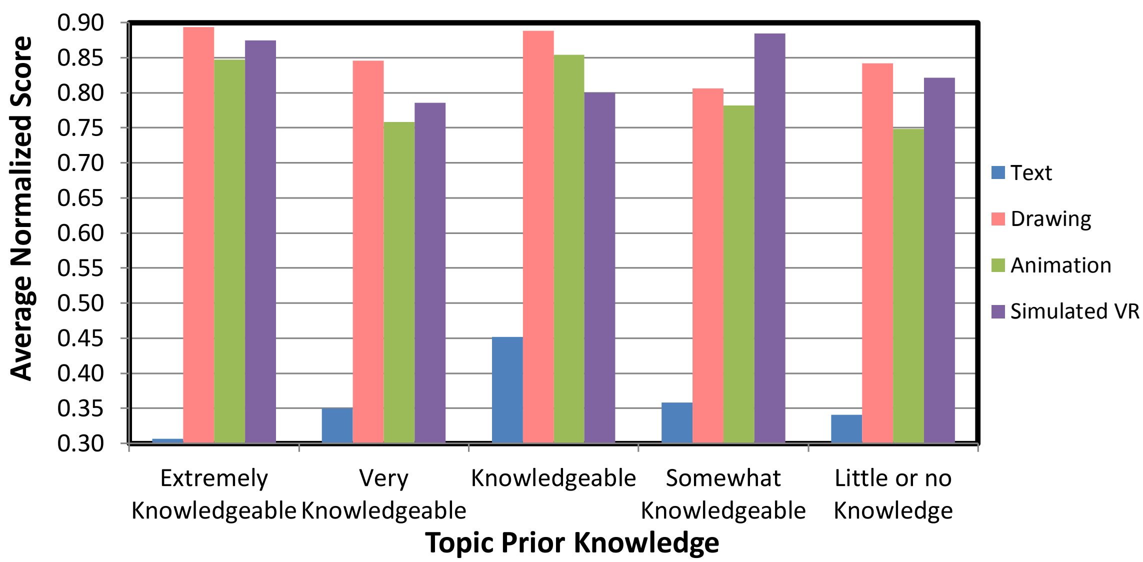


Figure 83. Multimedia preferences vs. prior knowledge of the topic.

To summarize the findings of the relationship between multimedia preferences and demographics, there were no statistically significant differences by gender, age, total engineering work experience, engineering work experience at John Zink, management level, highest engineering degree, specialty of the highest engineering degree, and prior knowledge of the topic. The only statistically significant difference was for age and engineering license for simulated VR preference. Interestingly, the oldest age group (>65) had the strongest preference, while an intermediate age group (36-45) had the weakest preference. Those without a license more strongly preferred simulated VR than those with a license.

Question #9: What is the relationship between engineers' learning strategy preferences and their multimedia preferences?

The relationship between participants' learning strategy preferences and their multimedia preferences is shown in Table 28 and Figure 84. An ANOVA did not show any statistically significant differences within a multimedia type as a function of learning strategy preference.

Table 28

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by learning strategy preference and ANOVA ($N = 107$, missing = 3, $df = 2$).

Learning Strategy Preference	Text	Drawing	Animation	Simulated VR
Navigator	.3396	.8807	.7696	.7718
Problem Solver	.3584	.8358	.7609	.8497
Engager	.2800	.7933	.7917	.8542
F	1.772	1.222	.199	1.801
p	.175	.299	.820	.170

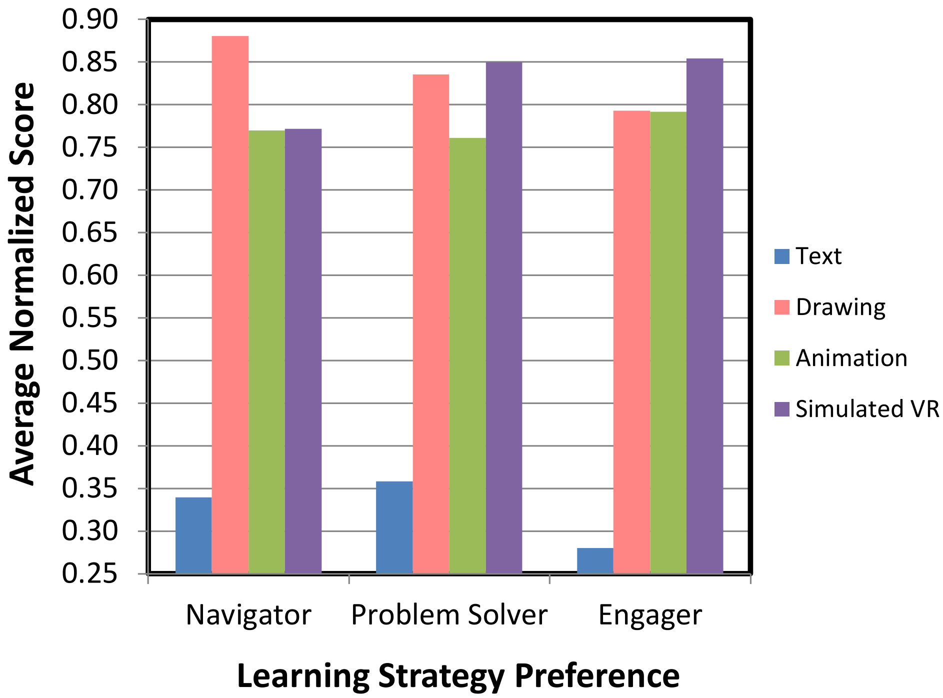


Figure 84. Learning strategy preferences vs. multimedia preferences.

Question #10: What is the relationship between engineers' verbal-visual cognitive styles and multimedia preferences?

The relationship between participants' verbal-visual cognitive style and their multimedia preferences is shown in Table 29 and Figure 85. According to an ANOVA, there were no statistically significant differences within a multimedia type as a function of the verbal-visual cognitive style. Similar data are shown in Table 30 and Figure 86 where the number of verbal-visual cognitive style categories has been reduced from seven to three. Again, an ANOVA did not show any statistically significant differences within a multimedia type as a function of verbal-visual cognitive style.

Table 29

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by verbal-visual cognitive style (7 categories) and ANOVA (N = 108, missing = 2, df = 5).

Verbal-Visual Cognitive Style	Text	Drawing	Animation	Simulated VR
Strongly more verbal	.0000	.0000	.0000	.0000
Moderately more verbal	.3740	.8900	.8220	.7820
Slightly more verbal	.4033	.8483	.8333	.7900
Equally verbal & visual	.4223	.9154	.7738	.8438
Slightly more visual	.3413	.8737	.7338	.7706
Moderately more visual	.3313	.8318	.7730	.8436
Strongly more visual	.3065	.7817	.7400	.8643
F	1.661	1.254	.643	.630
p	.151	.290	.668	.678

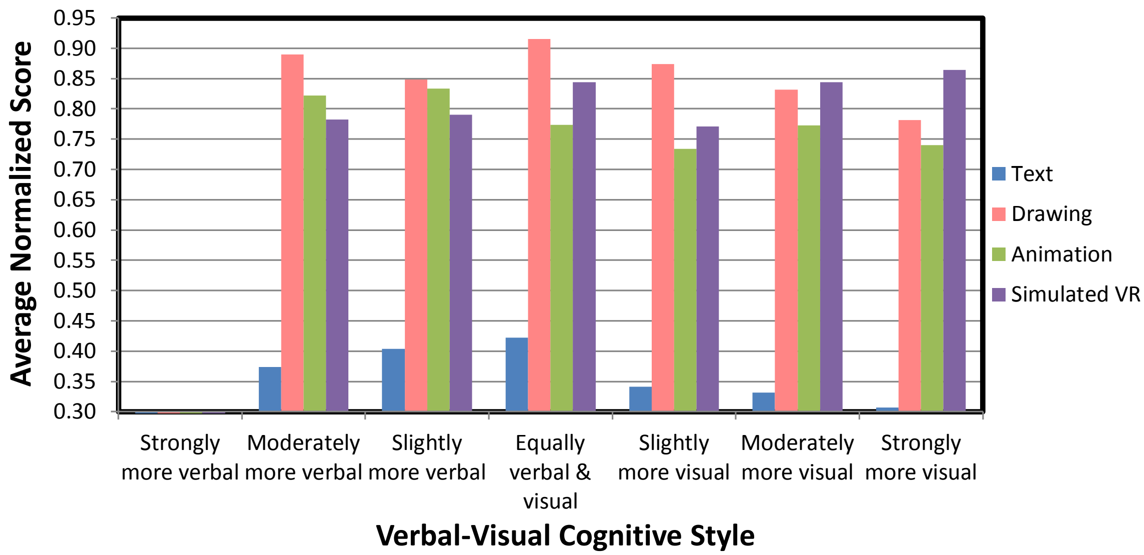


Figure 85. Verbal-visual cognitive styles (7 categories) vs. multimedia preferences.

Table 30

Comparison of mean normalized comparison scores for the verbal, static graphic, non-interactive dynamic graphic, and interactive dynamic graphic types by verbal-visual cognitive style (3 categories) and ANOVA (N = 108, missing = 2, df = 2).

Verbal-Visual Cognitive Style	Text	Drawing	Animation	Simulated VR
Verbal	.3740	.8900	.8220	.7820
Neither verbal nor visual	.3820	.8849	.7657	.8011
Visual	.3229	.8149	.7638	.8506
F	2.430	2.140	.319	.962
p	.093	.123	.728	.385

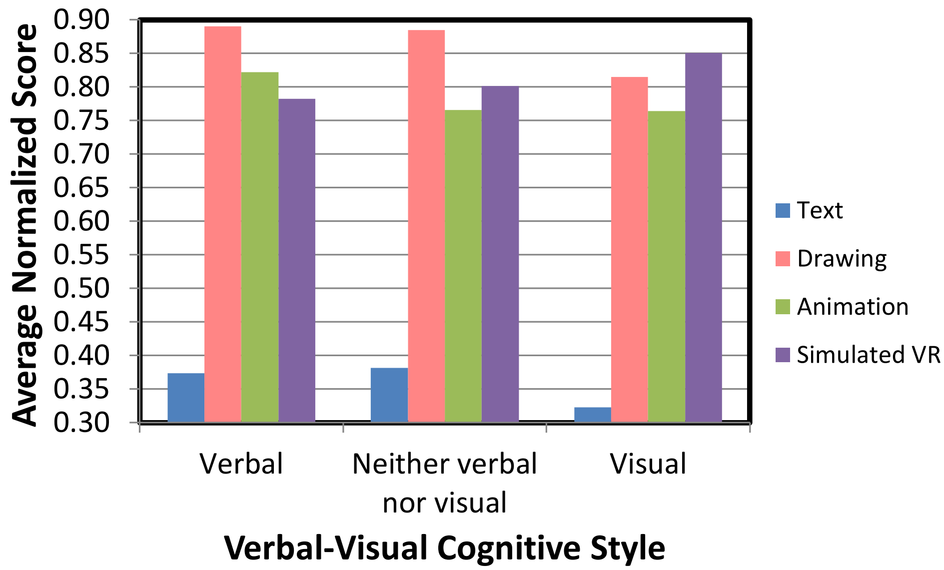


Figure 86. Verbal-visual cognitive styles (3 categories) vs. multimedia preferences.

Question #11: What is the relationship between engineers' learning strategy preferences and verbal-visual cognitive styles?

The relationship between participants' verbal-visual cognitive style and their learning strategy preference is shown in Figure 87. The profiles were not statistically different (χ^2 = 9.154, *df* = 10, *p* = .518). In Figure 88, the same data are shown but the number of cognitive style categories was reduced from seven to three. The profiles were not statistically different (χ^2 = 3.345, *df* = 4, *p* = .502).

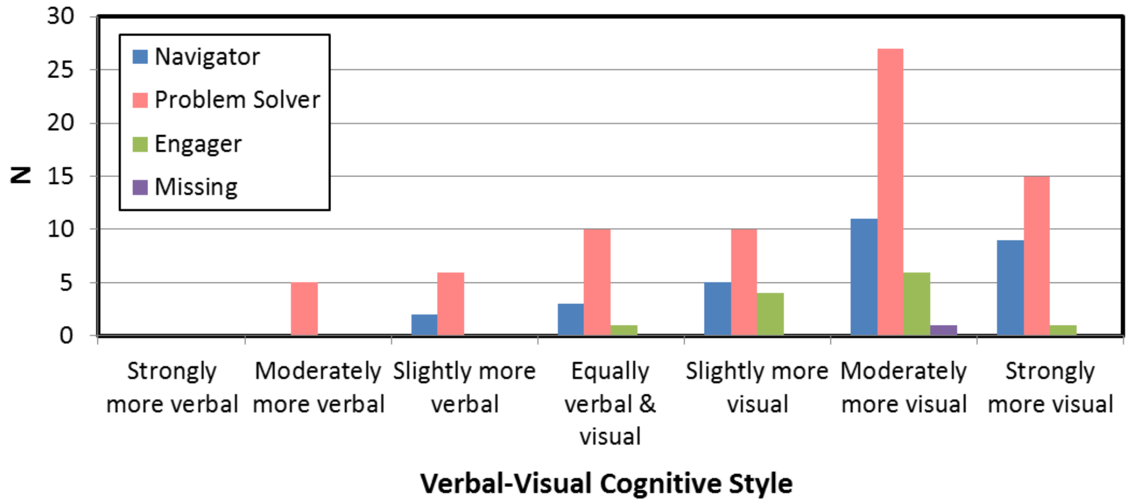


Figure 87. Verbal-visual cognitive styles (7 categories) vs. learning strategy preferences.

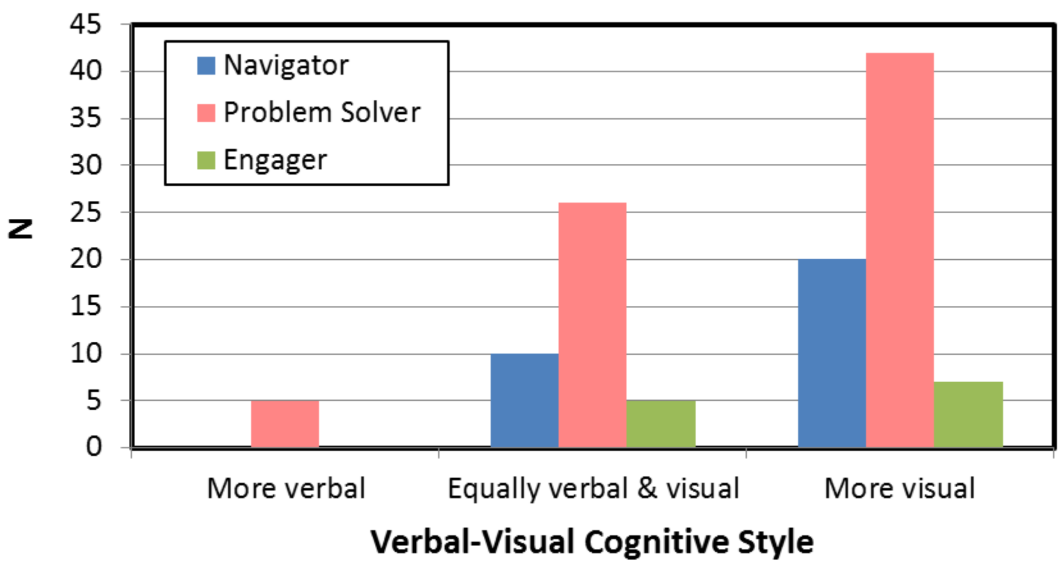


Figure 88. Verbal-visual cognitive styles (3 categories) vs. learning strategy preferences.

CHAPTER V

SIGNIFICANT FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Significant Findings

Multimedia Cone of Abstraction

Dale's Cone of Experience is an instructional design icon that has been used for decades to develop learning content. It was originally targeted at K-12 teachers and was developed before some of the modern technologies such as virtual reality were available to instructors. In this study, a theoretical advancement was updating Dale's Cone for adult learners and including today's instructional learning technologies. The new Multimedia Cone of Abstraction provided the conceptual framework for this study.

Learning Strategy Preferences of Working Engineers

The learning strategy preference profile of the working engineers in this study was statistically different than that of the general population, with significantly more Problem Solvers and fewer Engagers. This is a practical finding consistent with Sheppard et al.'s (2009, p. 3) description of engineering, "Engineering practice is, in its essence, problem solving."

Verbal-Visual Cognitive Style of Working Engineers

The measured verbal-visual profile of the working engineers in this study was statistically different than that of the general population, with many more visualizers than verbalizers. The profile of the working engineers in the study was also statistically different than the profiles of engineering students found in previous studies by Montgomery (1995), Rosati (1999), and Kirkham, Farkas, and Lidstrom (2006). This is a practical finding that can be used by instructional designers to develop more effective content for working engineers.

Multimedia Preferences of Working Engineers

Many have identified the importance of continuing engineering education and called for easier availability for working engineers to maintain their proficiency. One way to do that is through distance education. However, no research or guidelines were found in the literature for designing distance continuing engineering education. This study investigated one aspect of this gap in the literature – multimedia preferences of working engineers.

Previous research has shown that distance learning can be as effective as classroom learning. According to Bhowmick, Khasawneh, Bowling, Gramopadhye, and Melloy (2007, p. 615), "Choosing the appropriate multimedia for the learning modules or systems is critical to designing an efficient web-based asynchronous learning systems or modules." Research to date has not shown that any particular type of media leads to more learning than other types, assuming appropriate instructional design guidelines are followed. Garavan, Carbery, O'Malley, and O'Donnell (2010) experimentally found from a large sample of employees from a diverse range of organizations that e-learning instructional design was directly correlated with e-learning participation. Learner preferences were investigated in this study, under the assumption that using preferred media types would enhance learner motivation. The present study investigated two of the most important factors in the teaching-learning process: learner characteristics and instructional design including the integration of technology (Gulbahar & Yildirim, 2006).

One example of multimedia that has the potential to get the attention of learners is animations (Kirby, 2008). Betrancourt (2005, p. 293) wrote,

> Animations are attractive and intrinsically motivating for learners. However, they are hard to perceive and conceive, their processing requires a heavy cognitive load, and there is a chance that learners do not get any benefit from studying the animation compared with static graphics. In this context, and given the cost of designing animated graphics compared to static ones, the first question an instructional designer should ask is "Do I really need to use animation?" According to the research on animation, animation should be used only when needed, that is when it is quite clear that learners will benefit from an animation.

Moreno (2005) warned instructional designers about focusing too much on state-of-the-art technologies without considering how they relate to cognitive theory. This is a potential problem with multimedia such as virtual reality. There is a tendency to design distance learning materials based more on media technology than on sound instructional design principles (Carr & Carr, 2000). The present research showed that the most advanced technology, virtual reality, was not strongly preferred over other less advanced technologies such as static graphics.

Most instructional designers assume that dynamic graphics such as animations and virtual reality are preferred when motion is involved in a learning context. However, using static images that communicate motion can be as, and sometimes more, effective than using animations (Clark, 2005). Participants in this study slightly preferred a static graphic to both non-interactive and interactive dynamic graphics.

Another practical finding of this study is that the working engineers strongly preferred graphical multimedia over text which is consistent with their strong verbal cognitive style. In the within-multimedia category survey, they strongly preferred text over labels + narration, drawing over photograph, animation over video, and simulated VR over real VR. This was a somewhat surprising result as the less concrete graphics were preferred over the more realistic graphics.

This theoretical finding is not what might have been expected based on Dale’s Cone of Experience because most of the participants had relatively little prior knowledge of the topic and according to Dale’s hypothesis should have preferred more realistic multimedia. Both Dale’s Cone and the new Multimedia Cone of Abstraction suggest that instructional designers should provide more concrete materials to learners with less prior knowledge (novices). In this study, the novice learners preferred less concrete multimedia, although the preference was not strong.

There are at least two possible explanations for this finding, both related to the prior knowledge of the participants. The first is that, for example, a simple drawing may be preferred to a photograph which could provide too much detail (Travers, 1966) that might cognitively overload the learner with low prior knowledge. The second is that the participants’ prior knowledge changed during the course of the study. As they were exposed to more types of multimedia on the same subject, their prior knowledge level increased. Then, the less concrete multimedia may have been slightly more preferred than the more concrete multimedia because the participants had more prior knowledge after viewing the initial pairs of multimedia types. This explanation would support the realism theory that more realistic content is preferred for more novice learners and more abstract is preferred for more expert learners.

The participants strongly preferred text over narration. This might be a surprising result for non-engineering learners, as narration has the potential to be more concrete than text because of the added information from tone and voice inflection. However, for the engineering participants in this study, anecdotal evidence based on informal discussions with some of the participants suggested that visually seeing the description of each part was preferred to hearing it. That is consistent with their very strong visual cognitive style. Also, the narration in this study was monotone and did not include additional information from tone and voice inflection that would have made it more concrete compared to text alone.

The only statistically significant difference between multimedia preferences and demographics was for age and engineering license for simulated VR preference. The oldest age group (>65) had the highest preference and an intermediate age group (36-45) had the lowest preference for simulated VR. Those without a license more strongly preferred simulated VR than those with a license. There were no statistically significant relationships between learning strategy preferences and multimedia preferences or between verbal-visual cognitive styles and multimedia preferences.

Potential Confounding Variables

There were some potential confounding variables in this study. The participants in this study strongly preferred text over narration. However, this result should be used with caution as the real advantage of narration over text was not seen in this particular study. The component descriptions were very short and somewhat technical. There was no real opportunity for the narrator to use tone and inflection to add additional information over plain text. The narration used in this study was monotone. Future studies might further explore the comparison between text and narration for other topics and with other narrators, to see if the preferences found here extend to other learning contexts.

Another potential confounding variable was the added burner stand legs that appeared in the photograph (see Figure 15), in the video (see Figure 19), and in the real virtual reality multimedia types (see Figure 24). On the survey comparing the drawing to the photograph, participant A who slightly preferred the drawing to the photograph wrote, “Maybe just due to the legs; Photoshop them out.” Of the same comparison participant B who slightly preferred the photograph wrote, “Could you black out the burner stand?” The same participant B who slightly preferred the video wrote on the survey comparing the animation to the video, “I would like the real burner more if it didn't show the burner stand." For the same comparison, participant C wrote, "Bars got in the way of the left picture" which was the video.

Another potential confounding variable was that the labels remained on the screen for the verbal and static graphics multimedia types, but did not remain on the screen for the non-interactive and interactive dynamic graphics. One participant wrote of the comparison between the labels + text and the animation, "Can they both be on the same slide so the definitions are always visible and highlighted when selected?" Another participant made comments on the comparison between the drawing and the simulated VR which the participant slightly preferred the simulated VR. Of the drawing the participant wrote, "I like how this has all parts pointed @ and labeled at one time." Of the simulated VR the participant wrote, "Disadvantage here is there is no slide with all parts labeled and identified and defined at once."

The quality of the virtual reality simulations was lower than the other multimedia types because of limitations with the software used to create the simulations. This was especially noticeable when the zooming feature was used. Having simulations with at least comparable quality to the other multimedia types may have changed the results, especially since the simulated virtual reality was only slightly less preferred than the drawing.

Another potential confounding variable was the learner interactivity. In an actual online learning context, the learners themselves would control the speed of displaying materials by advancing content at their own pace. In this study, the materials were advanced at a predetermined pace (approximately one minute for all types). This was done purposely to remove pace as a variable in this study, because the participants did not have any individual control of the content. Animation and video have been classified here as non-interactive dynamic graphics, while simulated and real VR have been classified as interactive dynamic graphics. In this study, the participants did not actually have the opportunity to interact with any of the graphics.

Another potential confounding variable was the prior knowledge of the participants. Their self-selected prior knowledge was technically only correct for the first multimedia pair they viewed. After that, they would have had more prior knowledge than when they started the survey. Those that completed both surveys and viewed all ten multimedia pairs would likely have had significantly more prior knowledge when viewing the tenth pair than when they viewed the first pair. This was visually observed by the researcher as the participants completed their preferences for each multimedia pair much more quickly by the end of each survey. They appeared to spend less time on the subject matter and focused more on comparing multimedia types.

Conclusions

The findings from this study tentatively support several major conclusions, given the limited scope of the study. The sampled engineers had a learning strategy profile that was clearly different than the general population with significantly more Problem Solvers and fewer Engagers. Similar to the findings of Birzer and Nolan (2002) who found that police officers had a significantly different learning strategy profile compared to the general population, the results from this study suggest there may be an “occupational profile” for working engineers.

Another tentative major conclusion from this study is that working engineers are much more visual than the general population. This was supported by both the verbal-visual cognitive style preferences and by the multimedia preferences. This again suggests a potential occupational profile for working engineers.

Working engineers likely prefer more graphical multimedia to more textual multimedia. While the sampled engineers somewhat surprisingly slightly preferred more abstract graphics to more concrete graphics, there was not enough evidence and there were some potential confounding variables to prevent generalizing that finding into a conclusion. The preference for graphical over textual further supports an occupational profile for engineers.

The learning strategy preferences and verbal-visual cognitive styles were generally independent of demographics. This further supports an occupational profile as these overall preferences for the working engineers were different than the general population and independent of the demographics collected.

The multimedia preferences for the working engineers were generally independent of demographics. No data were found for multimedia preferences for the general population or other occupations to determine if the results for engineers' multimedia preferences support an occupational profile.

Further data collected in future studies that support the learning strategy preference, verbal-visual cognitive style, and multimedia preference profiles found in this study would confirm the occupational profile found here. This should have a profound effect on the design and delivery of learning content for working engineers compared to the general population. Engineers prefer more problem solving and more visual content than most people. However, based on this researcher's personal experience, current learning content for working engineers is generally designed the same as for the general population. Therefore, changes need to be made to make learning more effective for engineers. This was the primary objective of this study to find out more effective ways to teach working engineers.

Recommendations

Instructional Design

The popular adage "a picture is worth a thousand words" (Larkin & Simon, 1987; Mayer & Gallini, 1990; Mayer & Sims, 1994; Ollerenshaw, Aidman, & Kidd, 1997) may help to explain why the participants in this study strongly preferred visual graphics compared to verbal text, whether written or narrated. According to brain research, we take in more information visually than by any of the other senses (Wolfe, 2010). One of Bowman's (2011) six learning principles is that images trump words where graphics are recommended over text. That principle was supported in this study.

As with most things in life, too much of any one thing is often not optimal or even desirable. As the saying goes, “Variety’s the very spice of life” (Cowper, 1855, p. 74). Kemp (1975) recommended using a variety of multimedia types to meet both different instructional purposes and the various learning styles of students. In a book on designing technical training, Clark (1989) recommended using a variety of instructional media as there is no one type that is better than others. In reference to training and development, Hayes and Allinson (1996) recommended a variety of learning activities to meet the trainees’ needs of a range of learning styles. Jensen (2008, p. 57) wrote the following using sight and variety to enhance the learning process,

> Make lectures or presentations more compelling to the brain by using objects, photographics, graphics, charts, graphs, slides, video segments, bulletin board displays, and color. For maximum impact, change media frequently – from inspiring videos and vivid posters to mind maps, drawings, and symbols.

There are similar recommendations to use a variety of instructional methods in distance learning. In an ethnographic study of distance education students, Garland (1993) found some students wanted more and varied media to accommodate their learning styles. Gulbahar and Yildirim (2006) recommended using a variety of media types in online content to help motivate learners. Regarding the instructional design of distance learning materials, Simonson et al. (2012) recommended balancing variety with cost.

While there might be preferences for specific types, some variety is recommended. Further, multiple representations can help students develop deeper understanding (Ainsworth, 1999; McKenna & Agogino, 2004), which is particularly important for significant and challenging subjects. In engineering education, it is common to show an equation (a more abstract type of multimedia) along with a graph (a more concrete type of multimedia) to show how the variables in the equation are related. While strict duplication of multimedia types should be avoided (e.g., drawing and photograph that are essentially the same), concepts can be reinforced using different types of complementary multimedia. Bodemer, Ploetzner, Bruchmüller, and Häcker (2005) experimentally studied learners actively integrating static representations first before viewing dynamic representations on the same content. They found this can reduce the cognitive load of processing the dynamic representations, provide learner support, and result in enhanced learning. This was particularly the case for learners with lower prior knowledge. One of Medina’s (2014) 12 brain rules is referred to as *sensory integration*, where using multiple senses (e.g., audio, visual) can enhance learning. This suggests using multiple types of multimedia may enhance learning compared to using only a single type. Using multiple types for the same topic will also appeal to a wider range of student preferences.

Best practices for online presentations include giving learners as much control as possible (Horton, 2006). For example, passively watching a video or animation play through may not be as effective for learning as if it were interactive (Cherrett, Wills, Price, Maynard, & Dror, 2009). Höffler and Schwartz (2011) experimentally showed that learners who had control (referred to as self-paced) performed better than learners where the system set the pace (i.e., played through without stopping) when viewing animations. This suggests that interactive dynamic graphics may be preferred from a learner control perspective, although static graphics and non-interactive dynamic graphics can also include user control. For example, static graphics can be designed to gradually reveal more and more information on a screen where the learner controls the rate at which more information is added. Non-interactive dynamic graphics can be divided into shorter segments to give learners the chance to absorb information before revealing succeeding segments. Note however, depending on learner characteristics such as prior knowledge, some learners may not be able to take full advantage of learner controls (Brown, 2001; Granger & Levine, 2010; Lawless & Brown, 1997). Research has shown that learners with low prior knowledge may actually perform worse under their own control than under computer control because they have more trouble integrating new knowledge compared to those with higher prior knowledge with existing schema on the topic (Steinberg, 1989).

Related to enhancing learner control is tailoring learning environments for the individual needs of the learners (Goulding & Syed-Khuzzan, 2014). The present research indicates that working engineers have different learner characteristics (e.g., learning strategy preferences and verbal-visual cognitive styles) than the general population. Therefore, training materials for working engineers need to be designed accordingly. The potential exists for further tailoring of learning content for individual working engineers. While the present study showed relatively few relationships between demographics and learner characteristics, future studies of other groups of working engineers may show some dependencies. Custom-designed knowledge-based learning environments could be developed to match content with learner characteristics to further enhance learning.

A further important finding of this study is that working engineers prefer problem solving as a preferred learning strategy. Therefore, effective instructional design for this group should include a significant amount of problem solving. This is supported by brain research where including problem solving in learning activities, sometimes referred to as *problem-based learning*, enhances the learning process (Wolfe, 2010).

Future Research

There were many things that were not studied here which should be considered in future research. One area of theoretical interest is collecting more data on concrete vs. abstract multimedia as a function of prior knowledge. In the present study, working engineers with less prior knowledge slightly preferred more abstract multimedia over more concrete multimedia. This is not what current realism theory (more concrete or realistic materials should be used with novice or low prior knowledge learners and more abstract materials should be used with expert or high prior knowledge learners) would suggest. However, as previously discussed there may be some confounding variables that could explain this apparent discrepancy. Much more data is required before any definitive conclusions can be made such as discarding the realism theory.

Clark (1989) listed five types of technical training content: procedures, concepts, factual information, processes, and principles. The present study investigated only one particular type of subject matter – factual information. Future studies could investigate multimedia preferences for the other four types of technical content.

The particular topic studied here, components of a specific type of technology, did not include any motion. The dynamic media hypothesis states that dynamic graphics may be superior to static graphics for viewing topics that incorporate motion. Working engineers' preferences may be different for subject matter that has motion or movement (e.g., pistons moving in an engine), where dynamic graphics may be more strongly preferred than static graphics.

The effects of color compared to black-and-white were not considered in this study because the subject matter selected here was essentially black-and-white. In general, most of the equipment produced by JZHC has very little color in it. Other studies could compare engineers' preferences between black-and-white vs. color.

The impact of dimensionality on multimedia preference was not considered here. While the subject matter selected was three dimensional, only side views were shown, which made the static graphics (drawing and photograph) effectively two dimensional. This was done deliberately to avoid showing the top and bottom of the burner, which would have revealed some of the important intellectual property for this technology. It might be assumed that engineers would prefer three-dimensional over two-dimensional graphics, but other previous assumptions, such as the assumed preference for dynamic over static graphics, were not supported based on this study, so the effect of dimensionality should be investigated.

Other information on participants might be collected in future studies such as ethnicity, native country, and native language. A study of engineering students at two private Midwestern U.S. universities found that the learning strategy preference profiles for chemical engineering students, for students who were not born in the U.S., and for students whose native language was not English were statistically significantly different than the general population (Baukal, Ausburn, Matsson, & Price, 2013). The preferences of Asian, African American, and Hispanic/Latino engineering students warranted further study as their profiles were also different than the general population, although there were not enough participants in those categories for a valid statistical analysis. Similar differences might be found for working engineers in those demographics.

Much more work remains to be done studying working engineers in other industries, in other parts of the U.S., and in other parts of the world with different languages and cultures. This study only concerned engineers working at a medium-sized Midwestern U.S. manufacturing company in the combustion industry. It is possible that engineers working in other industries such as automotive, aerospace, and academia may have different preferences compared to those found in this study. Cultural differences in other locations may also impact preferences.

Future studies should investigate participants having demographics that were lacking in the present study. For example, there were relatively few participants over 65 and under 26 years old. There were not many participants who: had between 11 and 20 years of total work experience, were many senior managers, had a Ph.D., or were civil/structural engineers.

One of the limitations of the study was the quality of the VR object movies which were limited in image resolution and the number of images that could be woven together. The lower resolution was particularly evident when zooming into the image (see Figure 23 and Figure 26). The limited number of images was also evident because the object movie appeared somewhat choppy as the image was rotated. These limitations should be eliminated in future versions of object movie software. A related issue is that the participants did not have their own computers to manipulate the VR simulations. It would be useful to repeat some of the comparisons in this study with improved VR movies with more and higher resolution images, and where each participant has their own computer to manipulate the images. These might change the outcome of the multimedia preferences.

Related to improved VR object movies, it would be very useful in future studies to compare learning with actual objects compared to learning with virtual objects. This is important because it is not normally feasible for distant learners to use actual objects, but it is possible for them to use virtual objects. It would be important to know if virtual objects are as effective as using actual objects. In some instances, such as when objects are very large or very small, it may actually be preferred to use virtual objects instead of actual objects.

Cueing, also referred to as *signaling*, helps guide learners to essential information to be learned, emphasizes organization, highlights relations, and can reduce cognitive loads to enhance learning (de Konig, Tabbers, Rikers, & Paas, 2009; Mayer, 2005b). Research has shown that using color or coarse movement (referred to as *inherent content cues*) in animations for cueing is more effective than using artificial cues such as arrows that are not part of the content being studied (de Konig et al., 2009). Arrows are a common device used for cueing (Clark, 2005; Clark & Lyons, 2011) and were deliberately used here to make all of the multimedia considered in this study to be as informationally equivalent as possible and to minimize color cueing as a potentially confounding variable. Future studies could consider working engineers' preferences for multimedia with inherent vs. artificial cues.

Another potentially important piece of data that could be collected in future studies is to ask the participant what side of the room they were sitting on during the survey. This could then be compared to their preferences to see if there are any biases toward picking multimedia displayed either on the same side as the participant or on the other side.

No previous studies were found which examined the effectiveness of multi-image presentations for adult learners. Multi-image presentations are more feasible than ever given the increasingly more affordable cost of computers and projectors. Most of the previous single- vs. multi-image studies showed essentially the same content either sequentially or simultaneously, respectively. Future studies should use best practices for multi-image presentations and compare learning against single-image presentations to determine if learning is enhanced with multi-image presentations.

Other types of technology should be investigated in future studies as the subject matter to see what impact that might have on multimedia preferences. Related to that, a technology should be selected where there is a clearer distinction in prior knowledge and a larger proportion of participants with substantial prior knowledge compared to the present study to determine if prior knowledge significantly impacts multimedia preferences. To minimize the potentially confounding effects of increasing learner prior knowledge over the course of a study, it may be necessary to use different technologies for each comparison. In that type of research design, participants would only see a technology once, so their level of prior knowledge would not be changing over the course of the study. That would remove changing prior knowledge as a potentially confounding variable.

Future research should include some qualitative studies to collect more information on the thoughts and opinions of participants. This could provide some explanations for why participants prefer certain types of multimedia. In this study, some participants offered unsolicited written comments. These were helpful in identifying the legs of the burner stands as potential confounders. Qualitative feedback might also identify other aspects of instructional design that could be important. For example, one participant wrote, “I like to put the mouse over a part and have it tell me what is it.” This is useful feedback that could help improve instructional design. A qualitative study, such as a focus group, might provide other similarly useful information.

A general area for further research is to determine the verbal-visual profile of the general population as there currently does not appear to be any concensus in the literature where there are some significant disparities from different studies.

Final Thoughts

A new instructional design framework, the Multimedia Cone of Abstraction, was developed as part of this research. This new framework combines an older framework (Dale’s Cone of Experience) considered by many to be an icon for decades but which was not specifically research-based, with the much newer and highly research-based set of guidelines for using multimedia (Mayer’s Cognitive Theory of Multimedia Learning). The new Multimedia Cone of Abstraction should be a useful tool for instructional designers, regardless of whether the learners are engineers or not.

This was the first study found to consider the learning preferences of working engineers, who need to be actively involved in lifelong learning to maintain and enhance their knowledge and skills. Failure to do so in the subject area considered here can lead to, for example: accidents that damage equipment and injure people, reduced thermal efficiency, increased pollution emissions, and expensive unplanned equipment shutdowns.

The engineers sampled here were found to more strongly prefer problem solving compared to the general population. This is a particularly important finding for instructors who don’t have that same learning strategy preference, which is especially likely for those instructors who are not engineers (e.g, instructors teaching working engineers on non-technical subjects such as soft-skills training). The same is true for verbal-visual cognitive style where the sampled engineers were much more highly visual than the general population. While a variety of instructional techniques are recommended to meet the varied needs of learners, training for engineers should include more problem solving and be highly visual.

The multimedia preferences of the sampled engineers were not what were expected as they preferred more abstract materials, even though the majority was novice learners on the specific topic. This is counter to the theory that more novice learners should prefer more concrete (realistic) content. However, the preference found in this study for abstract over concrete was only slight. It was also somewhat surprising that the participants so strongly preferred text over narration. There were some potential confounding variables that may explain those findings, which should be investigated in future studies.

An important finding of this research is that the learning preferences of the sampled working engineers were more dependent on the participants’ occupation (engineering), than on other demographics such as gender, age, length of work experience, management level, highest engineering degree, specialty for the highest engineering degree, professional engineering license status, and prior knowledge of the topic. While this result should be used with caution given the very narrow limitations of the sampled population, it suggests the recommended instructional methods for working engineers of more problem solving and more visual content could be broadly applicable to engineers in other contexts such as those working in different industries and in different countries.

Based on this researcher’s many years of engineering and education experience, the instructional methods suggested by this study are not currently being consistently applied by most instructors teaching working engineers. This suggests that changes need to be made to improve learning effectiveness.

While many new and important results were found in this study, this should only be the start of research into how to best teach working engineers. Much more work needs to be done as the present study only investigated a single topic, in a single company, at a single point in time. Existing learning technologies such as virtual reality continue to advance and new technologies are expected to be developed in the future. These developments will likely impact the learning preferences of working engineers, who themselves are often at the cutting edge of technological developments. Effective methods for teaching working engineers should be a dynamic and fruitful area of future research.

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APPENDIX A – PHASE 1 SURVEY

Phase 1 Survey of JZHC Engineers' Multimedia Preferences

Date: July 26, 2013

Survey Version: A

Participant ID #

(Unique identifier so you won't have to fill out the demographic data, Learning Strategy Preference, and Verbal-Visual preference on pages 2 & 3 of this survey again for the Phase 2 survey).

Circle the appropriate number in each column.

Last digit of the year you graduated high school	Last digit of the year you were born	Last digit of your cell phone number	Last digit of your street address	Last digit of your home zip code	Last digit of the year you joined John Zink Co.
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

Demographic Data

Question	Circle Your Choice / Fill in the Blank
Gender	1 = Female 2 = Male
Age	1 = < 26 2 = 26 – 35 3 = 36 – 45 4 = 46 – 55 5 = 56 – 65 6 = > 65
Total engineering work experience	1 = 0 to 5 years 2 = 6 – 10 years 3 = 11 – 15 years 4 = 16 – 20 years 5 = 21 – 25 years 6 = > 25 years
Total engineering work experience at John Zink	1 = 0 to 5 years 2 = 6 – 10 years 3 = 11 – 15 years 4 = 16 – 20 years 5 = 21 – 25 years 6 = > 25 years
Management level at John Zink	1 = individual contributor (no direct reports) 2 = middle management (e.g., director, supervisor - have direct reports) 3 = senior management (e.g., vice president, CFO, president, etc.)
Highest engineering degree	1 = Bachelors 2 = Masters 3 = Ph.D. 4 = Other ______________________________
Specialty for highest engineering degree	1 = Chemical Engineering 2 = Civil/Structural Engineering 3 = Electrical Engineering 4 = Mechanical Engineering 5 = Petroleum Engineering 6 = Other ______________________________
Are you a licensed Professional Engineer (PE)?	1 = yes 2 = no

Your knowledge of the COOLstar ARIA burner (**fill in ONE circle only**):

○	○	○	○	○
Extremely knowledgeable (e.g., invented, design, test, or sell this burner)	Very knowledgeable (e.g., invented, design, test, or sell <u>original</u> version of COOLstar burner)	Knowledgeable (e.g., invented, design, test, or sell other types of process burners but not the COOLstar)	Somewhat knowledgeable (e.g., not that familiar with process burners but familiar with other types of burners)	Little or no knowledge about this technology (e.g., may have heard of or seen this technology but that's about it)

<u>Learning Strategy Preference</u> (use the blue 2-sided ATLAS sheet)

ATLAS page 1 result (fill in ONE circle only next to your learning strategy preference):

○ Navigator	○ Problem Solver	○ Engager

The description of your learning strategy group from the ATLAS Groups of Learners (page 2) is reasonably accurate in describing you as a learner.

○	○	○	○	○	○	○
Strongly agree	Moderately agree	Slightly agree	Neither agree nor disagree	Slightly disagree	Moderately disagree	Strongly disagree

<u>Visual-Verbal Preference</u>

In a learning situation, sometimes information is presented verbally (e.g., with printed or spoken words) and sometimes information is presented visually (e.g., with labeled illustrations, graphs, or narrated animations). Please place a check mark indicating your learning preference.

Fill in ONE circle only next to your visual-verbal preference.

○	○	○	○	○	○	○
Strongly more verbal than visual	Moderately more verbal than visual	Slightly more verbal than visual	Equally verbal and visual	Slightly more visual than verbal	Moderately more visual than verbal	Strongly more visual than verbal

Multimedia Pair #1

Preference (fill in ONE circle only)

	○	○	○	○	○	○	○	
Left Slide	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #2

Preference (fill in ONE circle only)

	○	○	○	○	○	○	○	
Left Slide	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #3

Preference (fill in ONE circle only)

Left Slide	○ Strongly prefer left slide	○ Moderately prefer left slide	○ Slightly prefer left slide	○ No preference	○ Slightly prefer right slide	○ Moderately prefer right slide	○ Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #4

Preference (fill in ONE circle only)

	○	○	○	○	○	○	○	
Left Slide	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

APPENDIX B – PHASE 2 SURVEY

Phase 2 Survey of JZHC Engineers' Multimedia Preferences

Date: August 2, 2013

Survey Version: D

Participant ID #

Use the same ID# from the Phase 1 survey.

ID# suggestion from Phase 1

Last digit of the year you graduated high school	Last digit of the year you were born	Last digit of your cell phone number	Last digit of your street address	Last digit of your home zip code	Last digit of the year you joined John Zink Co.
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

Participant ID#: ________________________ #: _______

(same as Phase 1 survey Participant ID#)

If you are not sure of your Phase 1 Participant ID#, please fill out the following information again.

Demographic Data

Question	Circle Your Choice / Fill in the Blank
Gender	1 = Female 2 = Male
Age	1 = < 26 2 = 26 – 35 3 = 36 – 45 4 = 46 – 55 5 = 56 – 65 6 = > 65
Total engineering work experience	1 = 0 to 5 years 2 = 6 – 10 years 3 = 11 – 15 years 4 = 16 – 20 years 5 = 21 – 25 years 6 = > 25 years
Total engineering work experience at John Zink	1 = 0 to 5 years 2 = 6 – 10 years 3 = 11 – 15 years 4 = 16 – 20 years 5 = 21 – 25 years 6 = > 25 years
Management level at John Zink	1 = individual contributor (no direct reports) 2 = middle management (e.g., director, supervisor - have direct reports) 3 = senior management (e.g., vice president, CFO, president, etc.)
Highest <u>engineering</u> degree	1 = Bachelors 2 = Masters 3 = Ph.D. 4 = Other ____
Specialty for <u>highest</u> engineering degree	1 = Chemical Engineering 2 = Civil/Structural Engineering 3 = Electrical Engineering 4 = Mechanical Engineering 5 = Petroleum Engineering 6 = Other ____
Are you a licensed Professional Engineer (PE)?	1 = yes 2 = no

Your knowledge of the COOLstar ARIA burner before starting the Survey (**fill in ONE circle only**):

○	○	○	○	○
Extremely knowledgeable (e.g., invented, design, test, or sell this burner)	Very knowledgeable (e.g., invented, design, test, or sell original version of COOLstar burner)	Knowledgeable (e.g., invented, design, test, or sell other types of process burners but not the COOLstar)	Somewhat knowledgeable (e.g., not that familiar with process burners but familiar with other types of burners)	Little or no knowledge about this technology (e.g., may have heard of or seen this technology but that's about it)

Learning Strategy Preference (use the blue 2-sided ATLAS sheet)

ATLAS page 1 result (**fill in ONE circle only next to your learning strategy preference**):

○ Navigator	○ Problem Solver	○ Engager

The description of your learning strategy group from the ATLAS Groups of Learners (page 2) is reasonably accurate in describing you as a learner.

○	○	○	○	○	○	○
Strongly agree	Moderately agree	Slightly agree	Neither agree nor disagree	Slightly disagree	Moderately disagree	Strongly disagree

Visual-Verbal Preference

In a learning situation, sometimes information is presented verbally (e.g., with printed or spoken words) and sometimes information is presented visually (e.g., with labeled illustrations, graphs, or narrated animations). Please place a check mark indicating your learning preference.

Fill in ONE circle only next to your visual-verbal preference.

○	○	○	○	○	○	○
Strongly more verbal than visual	Moderately more verbal than visual	Slightly more verbal than visual	Equally verbal and visual	Slightly more visual than verbal	Moderately more visual than verbal	Strongly more visual than verbal

Multimedia Pair #5

Preference (fill in ONE circle only)

Left Slide	○	○	○	○	○	○	○	Right Slide
	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #6

Preference (fill in ONE circle only)

Left Slide	○	○	○	○	○	○	○	Right Slide
	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #7

Preference (fill in ONE circle only)

Left Slide	○	○	○	○	○	○	○	Right Slide
	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #8

Preference (fill in ONE circle only)

	○	○	○	○	○	○	○	
Left Slide	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #9

Preference (fill in ONE circle only)

	○	○	○	○	○	○	○	
Left Slide	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Multimedia Pair #10

Preference (fill in ONE circle only)

	○	○	○	○	○	○	○	
Left Slide	Strongly prefer left slide	Moderately prefer left slide	Slightly prefer left slide	No preference	Slightly prefer right slide	Moderately prefer right slide	Strongly prefer right slide	Right Slide

Slide	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1 or 2) (1 = like most, 2 = like least)
Left Slide		
Right Slide		

Overall Multimedia Rating and Ranking

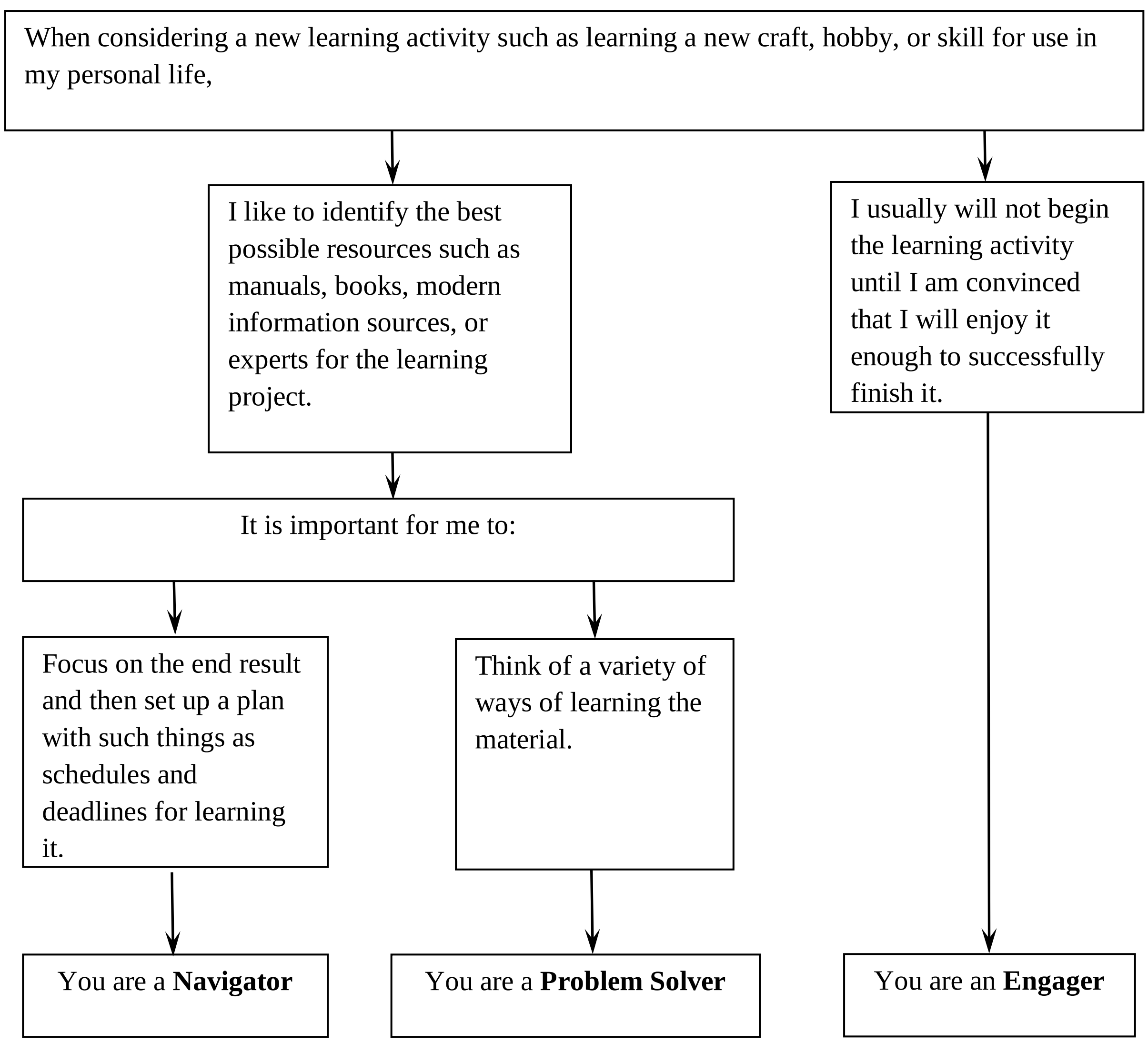
Multimedia Type	**Rating** from 0 to 100 (where 0 = hate it, 100 = love it)	**Ranking** (1, 2, 3 or 4) (1 = like most, 4 = like least)
Left slide, left image		
Left slide, right image		
Right slide, left image		
Right slide, right image		

APPENDIX C – ATLAS INSTRUMENT

ATLAS

(***A***ssessing ***T***he ***L***earning Strategies of ***A***dult***S***

Directions: The following statements are related to learning in real-life situations in which you control the learning situation. These are situations that are **not** in a formal school. For each one, select the response that best fits you, and follow the arrows to find the group to which you belong.



Groups of Learners

Navigators

Description: Focused learners who chart a course for learning and follow it.

Characteristics: Focus on the learning process that is external to them by relying heavily on planning and monitoring the learning task, on identifying resources, and on the critical use of resources.

Instructor: Schedules and deadlines helpful. Outlining objectives and expectations, summarizing main points, giving prompt feedback, and preparing instructional situation for subsequent lessons.

Problem Solvers

Description: Learners who rely heavily on all the strategies in the area of critical thinking.

Characteristics: Test assumptions, generate alternatives, practice conditional acceptance, as well as adjusting their learning process, use many external aids, and identify many resources. Like to use human resources and usually do not do well on multiple-choice tests.

Instructor: Provide an environment of practical experimentation, give examples from personal experience, and assess learning with open-ended questions and problem-solving activities.

Engagers

Description: Passionate learners who love to learn, learn with feeling, and learn best when actively engaged in a meaningful manner.

Characteristics: Must have an internal sense of the importance of the learning to them personally before getting involved in the learning. Once confident of the value of the learning, likes to maintain a focus on the material to be learned. Operates out of the Affective Domain related to learning.

Instructor: Provide an atmosphere that creates a relationship between the learner, the task, and the teacher. Focus on learning rather than evaluation and encouraging personal exploration for learning. Group work also helps to create a positive environment.

APPENDIX D – INSTITUTIONAL REVIEW BOARD APPROVAL

Oklahoma State University Institutional Review Board

Date:	Monday, March 04, 2013
IRB Application No	ED1320
Proposal Title:	Learning Strategy Preferences, Verbal-Visual Cognitive Styles, and Multimedia Preferences for Instructional Design of Continuing Engineering Education
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 3/3/2014

Principal Investigator(s):

Charles Baukal	Lynna Ausburn
10721 S Canton Ave	257 Willard
Tulsa, OK 74137	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

Participant Invitation

You are invited to participate in a voluntary study designed to determine the demographics, learning strategy preferences, verbal-visual cognitive styles, and multimedia (e.g., text, drawings, photos, videos, animations, and virtual reality) preferences of John Zink Hamworthy Combustion engineers in a learning context. The results of the study will be used to design more effective courses for the John Zink Institute. Anonymous surveys will be used to collect the information.

The study will be conducted in two phases. The first phase is estimated to take approximately 30 minutes and will determine preferences within different types of multimedia. It will also be used to collect some demographic information, verbal-visual preference, and learning strategy preference. The second phase is estimated to take approximately 15 minutes and will determine preferences between different types of multimedia. The second phase survey will be designed based on the results from the first phase. It is estimated there will be several weeks between the two phases. Refreshments will be available.

Please contact Chuck Baukal (charles.baukal@johnzink.com or 234-2854) if you have any questions.

Informed Consent

Project Title:	Learning Strategy Preferences, Verbal-Visual Cognitive Styles, and Multimedia Preferences of John Zink Hamworthy Combustion Engineers
Investigators:	Charles Baukal, Ph.D., John Zink Hamworthy Combustion Lynna Ausburn, Ph.D., Oklahoma State University
Purpose:	This study involves research to find out the demographics, learning strategy preferences, verbal-visual cognitive styles, and multimedia preferences of John Zink Hamworthy Combustion engineers. The purpose of this study is to determine this information that can be used to design more effective learning materials and teaching techniques for training engineers in the John Zink Institute.
Procedures:	The research will be conducted in two phases. In the first phase you will be asked to complete a survey to provide demographic, learning strategy preference, verbal-visual cognitive style, and preferences within different types of multimedia. In the second phase, expected to occur within several weeks of the first phase, you will be asked to complete a survey to provide preferences between different types of multimedia. Both surveys are anonymous. You will select a unique identifier that will be used to connect your responses to the two surveys.
Risks of Participation:	There are no known risks associated with this project which are greater than those ordinarily encountered in daily life.
Benefits:	The potential benefit of this research is improved learning for engineers.
Confidentiality:	The data from this study will be stored on a password-protected computer for up to seven years. The records of this study will be kept private. Any written results will discuss group findings and will not include information that will identify you. Research records will be stored securely and only researchers and individuals responsible for research oversight will have access to the records. It is possible that the consent process and data collection process will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research.
Compensation:	No compensation will be offered for participation.
Contacts:	Charles Baukal: charles.baukal@johnzink.com, (918) 234-2854 Lynna Ausburn: lynna.ausburn@okstate.edu, (405) 744-8322 If you have questions about your rights as a research volunteer, you

may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, (405) 744-1676 or irb@okstate.edu

Participant Rights: Participation is voluntary. Subjects can discontinue the research activity at any time without reprisal or penalty.

Consent: Completing and returning the survey will be taken as evidence of your willingness to participate and your consent to have the information used for the purposes of the study.

APPENDIX E – EXAMPLE SLIDE SET (PHASE 1, VERSION A)

Figure E1. Slide 1 for the Phase 1A survey.

Figure E2. Slide 2a for the Phase 1A survey.

Figure E3. Slide 2b for the Phase 1A survey.

Figure E4. Slide 2c for the Phase 1A survey.

Figure E5. Slide 3a for the Phase 1A survey.

Figure E6. Slide 3b for the Phase 1A survey.

Figure E7. Slide 3c for the Phase 1A survey.

Figure E8. Slide 4a for the Phase 1A survey.

Figure E9. Slide 4b for the Phase 1A survey.

Figure E10. Slide 4c for the Phase 1A survey.

Figure E11. Slide 4d for the Phase 1A survey.

Figure E12. Slide 4e for the Phase 1A survey.

Figure E13. Slide 5a for the Phase 1A survey.

Figure E14. Slide 5b for the Phase 1A survey.

Figure E15. Slide 5c for the Phase 1A survey.

Figure E16. Slide 6 for the Phase 1A survey.

Figure E17. Slide 7a for the Phase 1A survey (shown about halfway through the display).

Figure E18. Slide 7b for the Phase 1A survey (shown after complete slide had been displayed).

Figure E19. Slide 8 for the Phase 1A survey.

Figure E20. Slide 9 for the Phase 1A survey.

Figure E21. Slide 10a for the Phase 1A survey (shown about halfway through the display).

Figure E22. Slide 10b for the Phase 1A survey (shown after complete slide had been displayed).

Figure E23. Slide 11 for the Phase 1A survey.

Figure E24. Slide 12 for the Phase 1A survey.

Figure E25. Slide 13 for the Phase 1A survey (shown about halfway through the display).

Figure E26. Slide 14 for the Phase 1A survey.

Figure E27. Slide 15 for the Phase 1A survey.

Figure E28. Slide 16 for the Phase 1A survey.

Figure E29. Slide 17 for the Phase 1A survey (shown about halfway through the display).

Figure E30. Slide 18 for the Phase 1A survey.

Figure E31. Slide 19 for the Phase 1A survey.

APPENDIX F – EXAMPLE SLIDE SET (PHASE 2, VERSION D)

Figure F1. Slide 3 for the Phase 2D survey.

Figure F2. Slide 5 for the Phase 2D survey.

Figure F3. Slide 6 for the Phase 2D survey.

Figure F4. Slide 7 for the Phase 2D survey.

Figure F5. Slide 9 for the Phase 2D survey.

Figure F6. Slide 10 for the Phase 2D survey.

Figure F7. Slide 11 for the Phase 2D survey.

Figure F8. Slide 12 for the Phase 2D survey.

Figure F9. Slide 13 for the Phase 2D survey.

Figure F10. Slide 14 for the Phase 2D survey.

Figure F11. Slide 15 for the Phase 2D survey.

Figure F12. Slide 16 for the Phase 2D survey.

Figure F13. Slide 17 for the Phase 2D survey.

Figure F14. Slide 18 for the Phase 2D survey.

Figure F15. Slide 19 for the Phase 2D survey.

Figure F16. Slide 20 for the Phase 2D survey.

APPENDIX G – MISSING DATA

Table G1

Summary of missing values for demographic and learner preferences data.

Variable	*N*	Missing	
		Count	Percent
Gender	116	2	1.7
Age	117	1	.8
Total Work Experience	116	2	1.7
JZ Work Experience	117	1	.8
Management Level	115	3	2.5
Degree	116	2	1.7
Degree Specialty	114	4	3.4
PE License	117	1	.8
COOLstar Prior Knowledge	117	1	.8
Learning Strategy Preference	115	3	2.5
Verbal-Visual Cognitive Style	116	2	1.7

Table G2

Missing value pattern for demographic data.

Gender	Age	Total Work Exper.	JZ Work Exper.	Management Level	Degree	Degree Specialty	PE License	COOLstar Knowledge	Learning Strategy Preference	Verbal-Visual Cognitive Style
Female	46-55	6-10	6-10		Other	Other	No	Little or no Knowledge	Engager	Moderately more visual than verbal
Male	46-55	0-5	0-5	Individual Contributor	Other		No	Little or no Knowledge	Problem Solver	Strongly more visual than verbal
Male	46-55	16-20	16-20	Individual Contributor	Bachelors	Electrical Engineering	Yes	Little or no Knowledge		
Male	46-55	21-25	0-5	Individual Contributor	Masters	Mechanical Engineering	No	Knowledgeable		Moderately more visual than verbal
Male	46-55		>25	Individual Contributor	Other	Other	No	Little or no Knowledge	Problem Solver	Equally verbal and visual
Male	56-65	6-10	0-5				No	Very Knowledgeable	Problem Solver	Strongly more visual than verbal
Male	56-65	>25	>25	Middle Management	Other		No	Very Knowledgeable	Problem Solver	Strongly more visual than verbal
	46-55	21-25	11-15	Middle Management	Masters	Chemical Engineering	No	Somewhat Knowledgeable	Navigator	Moderately more visual than verbal

Shaded areas indicate missing data.

Table G3

Demographics of Phase 1 participants (all males) who did not take the Phase 2 survey.

#	Age Range (years)	Total Work Experience (years)	JZ Work Experience (years)	Management Level	Degree	Degree Specialty	Professional Engineering License	COOLstar Knowledge
1	26-35	0-5	0-5	Middle	Bachelors	Other	No	Little or no
2	26-35	6-10	0-5	Individual	Bachelors	Electrical	No	Little or no
3	26-35	6-10	6-10	Individual	Bachelors	Electrical	Yes	Little or no
4	36-45	16-20	6-10	Individual	Bachelors	Electrical	No	Little or no
5	46-55	0-5	0-5	Individual	Bachelors	Electrical	No	Little or no
6	46-55	>25	11-15	Individual	Bachelors	Electrical	No	Little or no
7	56-55	>25	>25	Individual	Masters	Mechanical	No	Somewhat
8	56-55	>25	>25	Middle	High School	N/A	No	Very

Table G4

Preferences of Phase 1 participants (all males) who did not take the Phase 2 survey.

#	Learning Strategy Preference	Verbal-Visual Preference	Verbal Preference	Static Graphic Preference	Dynamic Non-Interactive Preference	Dynamic Interactive Preference
2	Navigator	Slightly more visual	Text	Drawing	Animation	Simulated VR
3	Navigator	Strongly more visual	Text	Photograph	Video	Real VR
6	Problem Solver	Equally verbal & visual	Text	Drawing	Video	Simulated VR
7	Problem Solver	Slightly more verbal	Text	Photograph	Video	Real VR
1	Problem Solver	Slightly more visual	Text	Drawing	Animation	Simulated VR
5	Problem Solver	Slightly more visual	Text	Drawing	Animation	Simulated VR
4	Problem Solver	Slightly more verbal	Text	Drawing	Animation	Simulated VR
8	Problem Solver	Strongly more visual	Text	Drawing	Animation	Simulated VR

corresponds to the same # in Table G3.

APPENDIX H – RESULTS

Table H1

Respondents' age ranges.

Age Range	*N*	Percent
<26	11	9.3
26-35	28	23.7
36-35	22	18.6
46-55	30	25.4
56-65	22	18.6
>65	4	3.4
Missing	1	.8
Total	118	100.0

Table H2

Participants' work experience.

	Total		At John Zink	
Years	*N*	Percent	*N*	Percent
0-5	24	20.3	55	46.6
6-10	23	19.5	23	19.5
11-15	11	9.3	9	7.6
16-20	12	11.0	6	5.1
21-25	20	16.9	11	9.3
>25	25	21.2	13	11.0
Missing	2	1.7	1	.8
Total	118	100.0	118	100.0

Table H3

Participants' management level in John Zink.

	Population		Sample	
Management Level	*N*	Percent	*N*	Percent
Individual Contributor	133	76.4	88	74.6
Middle Management	31	17.8	22	18.6
Senior Management	10	5.7	5	4.2
Missing	0	0	3	2.5
Total	174	100.0	118	100.0

Table H4

Participants' highest engineering degree.

Highest Engineering Degree	*N*	Percent
Bachelors	78	66.1
Masters	18	15.3
Ph.D.	7	5.9
Other	13	11.0
Missing	2	1.7
Total	118	100.0

Table H5

Participants' engineering degree specialty.

Degree Specialty	*N*	Percent
Chemical Engineering	26	22.0
Civil/Structural Engineering	3	2.5
Electrical Engineering	19	16.1
Mechanical Engineering	50	42.4
Other	16	13.6
Missing	4	3.4
Total	118	100.0

Table H6

COOLstar ARIA burner prior knowledge.

Prior Knowledge	*N*	Percent
Extremely Knowledgeable	8	6.8
Very Knowledgeable	8	6.8
Knowledgeable	5	4.2
Somewhat Knowledgeable	18	15.3
Little or No Knowledge	78	66.1
Missing	1	.8
Total	118	100.0

Table H7

Participants' verbal-visual preference.

Verbal-Visual Preference	*N*	Percent
Strongly More Verbal than Visual	0	.0
Moderately More Verbal than Visual	5	4.2
Slightly More Verbal than Visual	8	6.8
Equally Verbal and Visual	14	11.9
Slightly More Visual than Verbal	19	16.1
Moderately More Visual than Verbal	45	38.1
Strongly More Visual than Verbal	25	21.2
Missing	2	1.7
Total	118	100.0

Table H8

Consolidated verbal-visual preference profile.

Verbal-Visual Preference	*N*	Percent
Verbal	5	4.2
Neither Verbal nor Visual	41	34.7
Visual	70	59.3
Missing	2	1.7
Total	118	100.0

VITA

CHARLES EDWARD BAUKAL, JR.

Candidate for the Degree of

Doctor of Education

Thesis: LEARNING STRATEGY PREFERENCES, VERBAL-VISUAL COGNITIVE STYLES, AND MULTIMEDIA PREFERENCES FOR CONTINUING ENGINEERING EDUCATION INSTRUCTIONAL DESIGN

Major Field: Education (Applied Educational Studies)

Biographical:

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Completed the requirements for the Doctor of Education in Applied Educational Studies at Oklahoma State University, Stillwater, Oklahoma in July 2014.

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